103

ELECTRIC VEHICLES AND ADVANCED BATTERY R&D

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Electric Vehicles and Advanced Batt...

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRD CONGRESS

SECOND SESSION

JUNE 30, 1994

[No. 170]

Printed for the use of the
Committee on Science, Space, and Technology

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*Ranking Republican Member.

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ELECTRIC VEHICLES AND ADVANCED BATTERY R&D

THURSDAY, JUNE 30, 1994

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON ENERGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:35 a.m., in room 2318, Rayburn House Office Building, Hon. Herb Klein (acting chairman of the subcommittee) presiding.

Mr. KLEIN [presiding]. Good morning.

Today the Subcommittee on Energy will examine the status and prospects for electric vehicle technology. Today's hearing will focus on several key issues.

First, is the U.S. automobile industry on track to develop and commercialize advanced technologies to meet electric vehicle requirements in California and other States? The State of California recently reaffirmed its requirement that the major automakers offer "zero-emission vehicles" starting in 1998. New York and Massachusetts have also adopted zero-emission vehicle mandates. In addition, 12 States in the Northeast region, from Maine to Virginia, plus the District of Columbia, have petitioned the U.S. Environmental Protection Agency for approval to adopt California's clean air standards. Policy developments in the northeastern States could potentially expand the scope of the electric vehicle market.

Such actions by the States add impetus to the technology development process, spurring efforts by the auto industry, other major corporations, and smaller R&D firms to develop advanced technologies for electric vehicles. Today we will assess: where we are now, and what is the outlook over the next several years for battery technologies and electric vehicles?

Secondly, we will assess the Federal Government's electric vehicle and advanced battery R&D programs. Both the Department of Energy and the Department of Defense Advanced Research Projects Agency are currently running electric vehicle technology programs intended to gear into commercialization efforts in the near to mid-term. What is the status of these programs? How are they related? What progress have they achieved?

What is ARPA's strategy for establishing a new electric vehicle industry? What are its prospects? What is its relationship to the existing auto industry? How does this compare with the activities of the Department of Energy, which is working with the Big Three automakers in the U.S. Advanced Battery Consortium?

The Big Three automakers have attempted to undercut electric vehicle mandates. Does this affect the pace of the industry's battery development work with DOE? What is the timetable for the Advanced Battery Consortium? Is it proceeding with sufficient urgency and resources to reflect a real commitment to the development of the electric vehicle industry?

Today we will hear from both the Energy Department and the Defense Department. We will also hear from the EPA, which is considering a petition from the 12-State Ozone Transport Commission, which includes my own State of New Jersey.

We will also hear from the Chairman of the U.S. Advanced Battery Consortium. In addition, we have with us today the CEOs of Solectria Corporation and the Ovonic Battery Company, two of the leading developers of electric vehicle technology. It's interesting to note that, recently, in the Tour de Sol electric vehicle race a Solectria car, powered by an Ovonic nickel metal hydride battery, started out in New Jersey and set a new record by traveling 214 miles on a single charge. Clearly, that represents a signal accomplishment.

Finally, we will hear from a representative of NESCAUM, the top air quality officials in the New England States, New York, and New Jersey. This group has done seminal work in moving the Northeast toward stronger environmental standards in the transportation sector, including the movement toward low-emission and zero-emission vehicles.

I think the bottom line is that we have many, many questions regarding the subject of electric vehicle technology, and although we spotlight this hearing on electric vehicle technology, it is part of a broader effort on the part of the Nation and this committee to find ways in which we can develop and manufacture vehicles that meet clean air standards, that are clean, that are efficient, and that limit our dependence upon foreign oil.

We welcome the distinguished panel of witnesses who are here today, and we look forward to their testimony.

In order to allow for additional written statements on the issues we are addressing today, the hearing record will be kept open for two weeks after this hearing.

I would also ask unanimous consent to enter Chairman Lloyd's statement in the record and make it part of the record.

[The prepared opening statement of Mrs. Lloyd follows:]

THE HONORABLE MARILYN LLOYD
SUBCOMMITTEE ON ENERGY
HEARING ON ELECTRIC VEHICLES AND ADVANCED BATTERY R&D
THURSDAY, JUNE 30, 1994

OPENING STATEMENT

Good morning. I would like to ask unanimous consent that today's proceedings be covered by the media. Without objection, so ordered.

Today the Subcommittee on Energy will consider the progress toward developing technologies to meet the need for marketable electric vehicles in this decade.

Both the Department of Energy and the Department of Defense have programs to support electric vehicle technology development. We have asked the DOE Office of Transportation Technologies and the DOD Advanced Research Projects Agency to join us today to explain their strategies for government-industry collaboration and to help the Subcommittee assess the progress of the federal electric vehicle and advanced battery r&d effort.

In addition, we will hear from industry witnesses whose firms are advancing the state of electric vehicle technology. The Subcommittee is interested in their assessment, as well as that of the federal agencies, regarding the outlook for advanced battery technologies and electric vehicles in the near- to mid-term.

Finally, the Subcommittee will receive information from the Environmental Protection Agency related to clean air policy and their recent discussions with a number of state representatives which could have direct bearing on the electric vehicle market.

All of these issues involve complex and difficult technical, economic, and environmental challenges. At the same time, we are presented with significant opportunities that could foster the growth of an electric vehicle industry that can provide efficient, environmentally sound transportation in the years and decades to come.

We look forward to your testimony.

Mr. KLEIN. And now at this time, I would like to recognize our ranking minority member, Mr. Fawell, for any opening statement he may have.

Mr. FAWELL. Fine, thank you, Mr. Chairman. I have a statement which I would like to have unanimous consent to be put into the record.

I look forward to the testimony. I know it was about a year ago that we went over this subject, and, obviously, electric vehicles and advanced battery R&D is a pretty important and daunting challenge that we have, as we look at California and New York and Massachusetts and the legislative deadlines and challenges they have set before us.

So I am interested in knowing how much progress, indeed, has been made and the changes that have taken place since roughly May of last year. So I look forward to hearing the testimony of the witnesses.

Thank you, Mr. Chairman.

[The prepared opening statement of Mr. Fawell follows:]

HONORABLE HARRIS W. FAWELL

OPENING STATEMENT

SUBCOMMITTEE ON ENERGY

HEARING ON "ELECTRIC VEHICLES AND ADVANCED BATTERY R&D"

JUNE 30, 1994

Madam Chairman, I would like to join you in welcoming today's witnesses.

Just a little over a year ago—on May 13, 1993—this Subcommittee reviewed the status of domestic electric vehicle (EV) development. It appears that some progress has been made, but we still have much to do if EVs are to overcome significant performance, cost and infrastructure hurdles.

Also, in the interim, the California Air Resources Board has reviewed and reaffirmed its requirement that, by 1998, 2 percent of all new vehicles lighter than 3,750 pounds sold by each manufacturer in that State—estimated to total about 40,000—be zero-emission vehicles, and ratcheting up to 5 percent by 2001 and 10 percent by 2003. Furthermore, the Northeast Ozone Transport Commission voted in February to petition the EPA to mandate the California standards throughout the Ozone Transport Region, which consists of 12 mid-Atlantic and Northeastern States and the District of Columbia.

While EVs appear to have great promise, I am concerned that the conflict between the proposed Government-imposed mandates and the reality of the state of EV technology could retard, rather than enhance, the near-term commercialization prospects of EVs. I believe that history has shown that mandates simply won't work. People will not be forced to buy or drive expensive, slow-moving or limited vehicles, and any attempt to coerce them into doing so may well produce a signifcant backlash.

In any event, Madam Chairman, I am interested in hearing our witnesses addressing these and other issues during today's session, and to hearing about a number of promising advances that have been made in batteries and in other EV technologies.

Mr. KLEIN. Thank you very much, Mr. Fawell.

And at this time I'd like to recognize the distinguished gentlelady from California, Ms. Harman, for an opening statement.

Ms. HARMAN. Thank you, Mr. Chairman.

As you know, I do not sit on this particular subcommittee of Science, Space, and Technology, but I have a keen interest in the subject matter and I appreciate you letting me show up this morning to make a couple of remarks.

First of all, I'd like to observe for the record that the 214-mile distance record that you noted was set in New Jersey, and that, obviously, is because New Jersey is a unique place, and I doubt that any electric vehicle could do as well in California. I want to say that.

Mr. KLEIN. I'm sure that California, if it tried real hard, could equal New Jersey's standards. [Laughter.]

Ms. HARMAN. The development of electric vehicle technology has been one of my priorities for the past year. It represents a way to improve our environment and a potential source of high-skill, high-wage jobs. One need only visit my congressional district in the south bay area of Los Angeles on a summer day to literally see how much needs to be done to combat our infamous smog problem. Electric vehicles offer the promise of tremendous improvements in air quality. Even when emissions from power plants are counted, EVs almost completely eliminate the emission of ozone-forming pollutants.

In addition to benefitting our environment, electric vehicle development represents a potential new market for our Nation's hard-hit aerospace and defense industries, and those are industries that I particularly focus on as a member of the Armed Services Committee and Science, Space, and Technology. CALSTART, a Southern California public-private consortium which includes many aerospace companies, has proven that defense technologies and skills can help create an advanced transportation industry. California and the Ozone Transportation Commission have led the way by requiring automakers to begin marketing zero-emission vehicles, and you did mention that, Mr. Chairman. Make no mistake, the market for electric vehicles is already here—from Torrance, California to Passaic, New Jersey. Federal electric vehicle research and development efforts must be focused on making this emerging technology commercially viable in the near future, and I certainly am committed to helping this happen.

Again, Mr. Chairman, I thank you for including me. I won't be able to stay for questions, but I did want to put two subjects on the table and I'm quite confident they'll be addressed. At any rate, the first is: California is home to the U.S. headquarters of the major Japanese automobile manufacturers, and it has occurred to me a long time that they might be a focus of our interest and energy, because they might go into the EV manufacturing business in California and elsewhere in the United States, even if the Big Three are reluctant to do so. And so I would hope we would consider that, and I see the panel nodding, and perhaps you already have.

The second thing is that, in environmental terms it's important to think about the recycling opportunities in this technology. Batteries and battery disposal is a polluting force. And if we can develop some sort of recycling aspects of batteries or a recyclable battery, I think this would be an enormous contribution, particularly in a place like California. So I would hope that some thought would be given to that.

Again, I thank you. I will continue to take an active interest in this subject on the full committee, and I'm honored that you would include me in your subcommittee hearing today.

Mr. KLEIN. Well, thank you very much, Ms. Harman, for your very, very important contribution, and we will make sure that the two questions you have raised, which are, indeed, important questions, are focused on during the course of the hearing. Thank you very much.

And now at this time I think we will proceed with the witnesses on panel one. The witnesses on panel one include Mr. Thomas J. Gross, the Deputy Assistant Secretary for Transportation Technologies, U.S. Department of Energy; Dr. Gary Denman, the Director of the Advanced Research Projects Agency, familiarly known as ARPA; and Mr. John C. Beale, the Deputy Director, Office of Policy Analysis and Review, Office of Air and Radiation, of the U.S. EPA.

We will—I think the way we're going to proceed is we will hear testimony from each of the three witnesses, and then after each of you, the three of you have completed, we will then proceed with questions. And I would just point out to each of you that your written statement, which has been submitted, will be made a part of the record. So you may summarize your testimony as you wish.

And now, without further ado, it is my pleasure to call upon Mr. Gross, although if the witnesses have any desire to proceed in any other order than the order in which I introduced them, that will be just fine.

Mr. Gross.

STATEMENT OF THOMAS J. GROSS, DEPUTY ASSISTANT SECRETARY FOR TRANSPORTATION TECHNOLOGIES, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC; ACCOMPANIED BY: GARY L. DENMAN, DIRECTOR, ADVANCED RESEARCH PROJECTS AGENCY, U.S. DEPARTMENT OF DEFENSE, ARLINGTON, VA, AND JOHN C. BEALE, DEPUTY DIRECTOR, OFFICE OF POLICY ANALYSIS AND REVIEW, OFFICE OF AIR AND RADIATION, U.S. ENVIRONMENTAL PROTECTION AGENCY, WASHINGTON, DC

Mr. GROSS. Thank you, Mr. Chairman.

Mr. Chairman, members of the subcommittee, and staff, I'm pleased to appear before you today to describe the Department of Energy's activities to develop and deploy electric vehicle technologies. In response to the Energy Policy Act of 1992 and President Clinton's commitment to achieving tangible results, we are proposing increased activities, in partnership with industry and other government organizations, to accelerate the availability and use of more fuel-efficient and alternatively-fueled vehicles. The need for action, leadership, and results in the transportation sector is becoming increasingly important. The gap between the transportation sector's demand for petroleum and our domestic production is steadily growing.

Another concern is the continued growth in the numbers of vehicles and miles driven, which is aggravating the air quality problems in our cities and increasing carbon emissions. The situation demands the development and deployment of new vehicle technologies and fuels which must compete successfully against reliable, proven, and highly-developed conventional products. This task will require major investments, sustained commitment, creativity, and a willingness to simultaneously pursue several technology pathways. Government support will be critical in overcoming numerous technical and institutional hurdles, given the magnitude of the investments required and the associated risks.

Our transportation strategy is to pursue multiple technology development paths that will increase the probability of success and will establish the basis for continuing advances over the decades ahead. In the area of advanced fuel-efficient vehicles, we support the development of hybrid propulsion, fuel cell, and improved energy storage technologies, lightweight materials and high-temperature materials technology, and more efficient heat engine technologies such as gas turbines. In the area of fuels, we support development of technologies that will provide competitive fuels from abundant domestic resources, and we fund activities to lower the cost, improve the performance, and accelerate the commercialization of vehicles that use alternative fuels, particularly natural gas, alcohols, and electricity.

The successful penetration of electric vehicles into the Nation's fleet would increase energy use efficiency and would enable the transportation sector to reduce its substantial—its great dependence on petroleum. In addition, both greenhouse gas emissions and urban pollution would be reduced. Overall, fuel-use flexibility would increase, and large economic gains could result from the creation of a domestic electric vehicle industry.

Currently, the most important driver for electric vehicle development is California's mandate requiring that at least 2 percent of new automobiles offered for sale there in 1998 be zero-emission vehicles. This rises to 10 percent by the year 2003. Currently, only electric vehicles can meet the zero-emission standard.

The ZEV mandate is one provision of the low-emission vehicle program which was mandated by the California Air Resources Board in 1990 to comply with the Federal Clean Air Act requirements. Facing similar pressures, several northeastern and mid-Atlantic States have adopted versions of the LEV program, including the ZEV requirement in some cases. In addition, States such as Florida, Illinois, Texas, Wisconsin, and Washington may consider adopting California-type mandates to meet their clean air attainment goals.

Responding in part to the 1998 ZEV deadline, the major U.S. automakers have launched substantial electric vehicle development efforts. Limited production prototypes are now undergoing controlled fuel testing and evaluation by consumers and fleet users. Currently, the major limiting factors for electric vehicle technology are high cost, restricted operating range, and lengthy refueling times.

Since the battery is the main component affecting these factors, advanced battery technology remains, in our view, the key to successful commercialization of electric vehicles. Most of today's electric vehicles are powered by lead acid and, to a lesser extent, nickel cadmium batteries. Lead acid batteries are constrained, however, by their relatively short service life and limited vehicle range. Nickel cadmium batteries have high initial cost and create significant environmental challenges. DOE believes, however, that there are other types of batteries that, when fully developed, would be able to provide the 100-mile range and above that market studies indicate is necessary to meet the travel requirements of many urban consumers.

Advanced battery development for electric vehicles is one of DOE's most visible and well-funded transportation programs. Since the late 1970s, research efforts in the United States, largely supported by DOE and the utilities, have achieved significant advances with several battery types. However, no single advanced battery technology has emerged as the third choice for making electric vehicles competitive in the marketplace.

In October 1991, therefore, we joined forces with the United States Advanced Battery Consortium, a partnership among Chrysler, Ford, and General Motors. The electric utility industry, represented by the Electric Power Research Institute, also supports the consortium through a participation agreement. This joint effort has resulted in improved program focus, more productive industry-government coordination, better defined battery requirements, and improved competition among battery developers.

Through Fiscal Year 1994, the Department has obligated $77 million to the $260 million 50–50 cost-shared program. Twenty-six point five million dollars is being sought for support of the USABC in Fiscal Year 1995.

Current research and development efforts of the USABC are directed at the four most promising advanced battery technologies identified for meeting the mid-term and long-term technical objectives. These are sodium sulfur, nickel metal hydride, lithium polymer, and lithium iron disulfide. The USABC has placed R&D contracts with six teams of battery developers and has signed cooperative agreements with several Department of Energy laboratories to develop and test these technologies. Prototype hardware delivered by the USABC contractors is currently undergoing rigorous laboratory and field testing.

The third page of some handout materials, which I hope you have in front of you and which I brought along for your review, provides a list of the contractors. The fourth page indicates the national laboratories that are involved in this program.

Our forward strategy will continue to focus primarily on battery technology development. The first phase of cooperative R&D efforts with the USABC will be completed at the end of Fiscal Year 1995. We're confident that contracts initiated during Fiscal Years 1992 to 1994 will produce at least one mid-term battery system for initiating validation and pilot plant design in 1996. A realistic target date for large-scale production is about the year 2000, after successful pilot plant production and extensive field test evaluation.

Efforts will continue on further battery testing, cost reduction, and the important environmental, health, and safety issues. Planning is underway to extend the cooperative program beyond Fiscal

Year 1995 to more thoroughly explore battery technologies capable of meeting the long-term goals. This effort is critical, we think, to realizing the full commercial potential of electric vehicles in establishing an internationally-competitive advanced electric vehicle battery industry in the United States.

The specialized resources of the DOE laboratories allow industry and government programs to test and evaluate emerging technologies and proof-of-concept vehicles under conditions that simulate actual vehicle operations and environments. Since the early 1980s, a broad range of state-of-the-art vehicles and components have been tested at several DOE laboratories.

Electric drivetrain technology is another important part of the equation. Recent years have seen a move from direct current toward alternating current drivetrains, which offer reduced size and weight, improved efficiency and higher reliability. Electric drivetrain technology is considered to be sufficiently mature to enable a manufacturer of performance-competitive electric vehicles as soon as adequate battery technology becomes available.

To ensure that the first generation of mass-marketed electric vehicles is problem-free and capable of gaining consumer acceptance, automakers, the electric utility industry, and government are cooperating in field trials to test vehicles under realistic conditions and to assess consumer response. The Department has been involved with several efforts to introduce electric vehicles into government and private fleets. The site operators program is a joint effort by government, utilities, and educational institutions to test and evaluate electric vehicles. Participants are currently operating 120 vehicles with an additional 50 to be added this year. Vehicles being tested are provided by original equipment manufacturers, as well as by the smaller conversion companies. Under our Federal fleet acquisition program, we are working with GSA and other agencies to purchase 10 to 15 electric vehicles for the Federal fleet this year.

Electric utilities, of course, have shown a significant interest in purchasing and using electric vehicles. A number of parties—the Edison Electric Institute, the Electric Transportation Coalition, and EPRI—have initiated the EV America Program and have formed a steering committee to increase the number of electric vehicles being demonstrated. The EV America plan includes Federal and/or other government support.

We are currently participating in discussions with creators of this concept to explore possible ways of integrating the ongoing site operators program and the Clinton administration's targets for alternative fuel vehicle acquisition into the Federal fleets into a cooperative, more aggressive, and better coordinated electric vehicle deployment campaign.

You had mentioned, Mr. Chairman, the Tour de Sol. I'd like to just mention that, among other activities that the DOE supports, we support a number of student competitions and also events such as the Tour de Sol and the Phoenix 500, and are always quite pleased when vehicles which are incorporating the technologies, in this case that have emanated from the U.S. Advanced Battery Consortium activity, are doing so well and are showing such significant progress recently.

DOE recognizes the importance of more effectively linking electric vehicle research, development, and deployment activities which are supported by the various Federal agencies. We chair an Interagency Coordination Task Force on Electric and Hybrid Vehicle Technologies, which includes representatives from nine agencies. DOE has been working particularly with the Advanced Research Projects Agency, the Federal Transit Administration, and the Department of Commerce, and has recently signed an initial Memorandum of Understanding with ARPA.

Mr. Chairman, you have brought together in panel two today some of the major contributors to achieving the breakthroughs needed to make electric vehicles viable in the marketplace. Their technical expertise, ingenuity, and determination are unmatched. With continued support of their organizations and other outstanding organizations like them, with the support from government and private sources, we will soon break through longstanding barriers to electric vehicle success. The DOE has been at the forefront of many technology advances that are steadily bringing us closer to viable electric vehicles and the realization of the associated national benefits. On the basis of our record of technical achievements, our specialized laboratory resources, and our history of cooperative programs with industry, DOE is in a position to further support the growing interest in electric vehicle technology development. We believe that the successful commercialization of electric vehicles will contribute substantially to attainment of important national energy, environmental, and economic goals.

Thank you. I will be pleased, Mr. Chairman, to respond to any questions.

[The prepared statement of Mr. Gross follows:]

STATEMENT OF THOMAS J. GROSS

DEPUTY ASSISTANT SECRETARY

OFFICE OF TRANSPORTATION TECHNOLOGIES

ENERGY EFFICIENCY AND RENEWABLE ENERGY

U.S. DEPARTMENT OF ENERGY

BEFORE THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

JUNE 30, 1994

Mr. Chairman and Members of the Subcommittee, I am pleased to appear before you today to describe the Department of Energy's activities to develop and deploy electric vehicle technology. Historically, the Department has led support for the development of transportation-related technologies. In response to the Energy Policy Act of 1992 and President Clinton's commitment to achieve tangible results, we are proposing increased activities to accelerate the use of more fuel-efficient and alternative fuel vehicles. Together with other Federal agencies, the Department is an active participant in deliberations which will determine our future policies. We are building on existing partnerships with both industry and government organizations to create exciting new partnerships.

The need for action, leadership, and results in the transportation sector is increasingly critical. The gap between the transportation sector's demand for petroleum and our domestic production continues to widen, and the growth in vehicles and number of miles driven is reducing our ability to control pollution. Despite advances in emissions control technology that have reduced emissions per vehicle dramatically, numerous cities across the country are still in non-attainment for ozone and carbon monoxide because of transportation contributions. Furthermore, transportation's share of carbon emissions (global warming gases) is approximately one-third of all U.S. carbon emissions, and total transportation carbon emissions are expected to rise 23% by 2010.

Competing successfully with conventional propulsion systems and fuels will continue to be a daunting challenge. Our current cars and trucks have the benefit of decades of refinement in design, materials and production techniques; reliability; low operating costs; and ease in refueling. Changing current fuel use and emissions projections will require successful development and deployment of new vehicle technologies, or substantial changes in our driving habits, or both. This is a challenging endeavor that will require sustained commitment, significant investment and willingness to pursue multiple technology paths.

Allow me to provide some perspective on the magnitude of the investment required to bring about change in our transportation system. Bringing a new vehicle model to market--using existing conventional technologies--may require four to six years and billions of dollars. For example, publicly available information indicates that the recently introduced Saturn required $5 billion to develop. Successfully introducing a new engine for an existing vehicle model may require an investment of a billion dollars. Commercializing breakthroughs in vehicle and fuel technologies will be financed principally by the private sector. Government's financial contribution will be relatively minor. Public investment, however, will continue to be critical to help overcome numerous technical and institutional hurdles.

The primary elements of the Clinton Administration's transportation strategy at the Department of Energy can be stated fairly simply:

Goal: achieve the important national benefits of

1) energy security and diversity;
2) greatly reduced emissions from mobile sources; and
3) more competitive U.S. vehicles and fuels industries.

Strategy: support the development and commercialization of

1) Advanced vehicle propulsion technologies which will enable substantial increases in vehicle fuel economy; and

2) Cost-competitive domestic alternative fuels, including electricity.

Pursuing multiple paths increases the probability of success, and establishes the basis for continuing advances over the decades ahead. In the area of advanced fuel efficient light duty vehicles, we support:

- Hybrid propulsion systems;
- Transportation fuel cell development;
- Improved energy storage technologies;
- Lightweight materials technology;
- More efficient heat engine technologies, e.g., gas turbines; and
- Materials with improved properties, e.g., at high temperature operation.

In the area of fuels, we support:

- Technologies that provide abundant, cost-effective fuels from domestic resources, specifically biomass;
- Technology development to lower the cost and improve performance of vehicles that use alternative fuels, particularly natural gas, alcohols and electricity; and
- Activities to accelerate the introduction and commercialization of alternative vehicles/fuels that are available and can be competitive with conventional fuels and vehicles.

The successful penetration of electric vehicles into the Nation's fleet would allow the transportation sector to meet part of its demand for energy with electricity and increase its energy efficiency. Since only about 4 percent of our electricity is generated from petroleum, this substitution would also reduce the sector's near total dependence on petroleum fuels. In addition, the use of electricity to meet transportation energy needs would provide greater fuel flexibility, and would open new opportunities for renewable energy use. Moreover, relative to internal combustion engine vehicles, vehicles powered by centrally generated electricity will help to reduce both greenhouse gas emissions and urban pollution problems. Large economic gains could also result from the creation and expansion of domestic and international markets for domestically produced electric vehicles.

Zero Emission Vehicle Regulations

It is widely believed that the most important driver for electric vehicle development is California's mandate requiring that at least two percent of new automobiles offered for sale in that state beginning in 1998 be zero emission vehicles (ZEVs). That minimum rises to 5 percent in 2001, and 10 percent in 2003 and thereafter. Currently, only electric vehicles can meet the zero-emission standard. The ZEV mandate is one provision in a set of stringent regulations that is known as the Low Emission Vehicle (LEV) Program, which was mandated by the California Air Resources Board (CARB) in 1990 as a means to comply with the Federal Clean Air Act's requirement that states achieve minimum ambient air quality standards. Facing similar pressures in the Northeast, Massachusetts and New York have also adopted California's LEV program, including the ZEV requirement. Other Northeastern and some mid-Atlantic states have agreed to adopt other versions of the LEV program. In addition to California and the Northeast, which have the most serious non-attainment problems in the country, states such as Florida, Illinois, Texas, Wisconsin, and Washington may consider adopting California-type mandates to meet their attainment goals. If all of the states that have expressed interest in adopting California's program do so, cumulative ZEV production could reach one million by 2003 (CARB estimate).

Status of EV Technology

Responding in part to the 1998 ZEV deadline, the "Big Three" United States automakers have launched major electric vehicle development efforts. Their current focus is on a limited number of electric vehicles for customer evaluation. General Motors' Impact electric car, Ford's Ecostar light-utility electric van, and Chrysler's TEVan represent the leading edge of this technology, and are now undergoing controlled field testing and evaluation by consumers and fleet users. Other non-automotive and small manufacturing companies are actively involved in developing and testing a range of electric vehicles and components. These efforts are receiving key support from DOE and other Federal agencies, California and other state agencies, regional authorities, the Electric Power Research Institute (EPRI), and electric utilities.

Ultimately, market acceptance will depend on the ability of electric vehicles to provide the range, durability, performance, and other amenities that consumers have come to expect from automobiles and light trucks. Very importantly, their cost will also have to be comparable to that of conventional vehicles. The major limiting factors for electric vehicle technology are the high differential cost, restricted operating range, and lengthy refueling times. Since the battery is the main component affecting these factors, advanced battery technology remains the key to successful commercialization of electric vehicles.

One of the Department's most visible and well-funded transportation programs is battery development for electric vehicles. Development of viable electric vehicles, with characteristics that make them attractive for a large number of consumers, is an important objective. In October 1991, the Department of Energy joined forces with the United States Advanced Battery Consortium (USABC). This combined effort has resulted in improved program focus; more productive industry-government coordination; development of more definitive battery requirements and specifications; and improved competition among battery developers. Costs of the program are split evenly between the Federal government and private sector participants. Through fiscal year 1994, the Department has obligated $77 million toward the government's share of a $260 million joint program, and is seeking $26.5 million in fiscal year 1995.

Most of the electric vehicles on the road today are powered by lead-acid and, to a lesser extent, nickel-cadmium batteries, each of which is available from several manufacturers worldwide. The primary disadvantages of the lead-acid battery are its short service life and limited vehicle range. Market studies have shown that electric vehicles need to have a minimum useable range between battery recharges of 100 miles before they will be accepted in the marketplace. The range of General Motors' Impact electric vehicle (with lead-acid batteries) is conservatively rated at 70 miles on the urban driving cycle and 90 miles on the highway cycle. Most other electric vehicles with lead-acid batteries have even smaller ranges. Field experience shows that lead-acid battery packs have a service life of, at best, three years, which means significant battery replacement costs. Nickel-cadmium batteries would offer a somewhat better operating range and could potentially last the life of the vehicle, but their initial cost is very high and cadmium poses significant environmental protection challenges.

The Department believes there are a number of advanced batteries that, when fully developed, would be able to easily provide the 100 mile range necessary to meet the commuting, shopping, and other daily travel requirements of many urban consumers. For example, the Ford Escostar, a light-utility electric van with advanced sodium-sulfur batteries, has demonstrated a 130 mile urban range. Other candidate technologies that could meet mid-term battery needs include nickel/metal hydride and sodium/nickel chloride batteries. For the long-term, the most promising battery candidates include high-temperature lithium/iron disulfide and ambient-temperature lithium/polymer batteries. If long-term batteries can achieve the development goals established by the USABC, they will enable electric vehicles to be fully competitive with conventional vehicles.

Electric drivetrain technology (including motor, controller, and transmission) is another important part of the equation. Although direct-current drivetrains have traditionally been used for electric vehicles, recent years have seen a move toward alternating-current (AC) drivetrains, which offer reduced size and weight, improved efficiency, and higher reliability. This trend is being driven by continuing advances in power electronics and controllers, motor design, and related areas. With the improvements expected by 1995, AC motors and controllers are expected to weigh only one-fourth as much as their 1980 counterparts. The state of electric drivetrain technology is considered to be sufficiently mature to enable the manufacture of performance-competitive electric vehicles as soon as an adequate battery technology becomes available. DOE has had a key role in advancing electric drivetrain technology to this stage, as will be discussed later.

To ensure the successful commercialization of electric vehicles, it is important that the first generation of mass-marketed vehicles be problem-free and capable of gaining consumer acceptance. Therefore, original equipment manufacturers (OEMs) and technology developers know they must field test their pre-production and prototype vehicles and components under realistic operating conditions, and then respond to constructive feedback. The automakers and the electric utility industry are cooperating in field trials to determine how potential customers will respond to electric vehicles under actual use circumstances. General Motors' PrEView Drive Program, which is being conducted in cooperation with leading utilities throughout the United States, is an example. Under this program, over 1,000 consumers across the country are being given the opportunity to test drive the Impact electric car for two to four weeks. DOE has also been actively involved in field testing new electric vehicle and component technologies through its Site Operator program.

Electric utilities have shown a significant interest in purchasing and using electric vehicles. The Electric Vehicle Association of the Americas, the Edison Electric Institute, the Electric Transportation Coalition, and EPRI have initiated the *EV America* program and have formed a joint ad hoc steering committee to promote the large-scale demonstration and early market introduction of electric vehicles (EVs). This program seeks to incrementally place up to 5,000 road-worthy EVs in a controlled market demonstration. The Chief Executive Officers of major electric utilities have been invited to participate in the program, and several have signed on. The *EV America* plan also calls for Federal and/or other government support. The Department has participated in recent discussions with creators and leaders of the *EV America* concept. We are exploring possible ways of integrating the on-going Site Operator Program, and the Clinton Administration's targets for alternative fuel vehicle acquisition in the Federal Fleets, into an *EV America* concept which can help achieve market introduction objectives.

Utilities, auto companies, and agencies at all levels of government are working together to develop the sales, service, and electricity infrastructure needed to support electric vehicles as they enter commercial service. The Infrastructure Working Council (IWC), which was initiated by EPRI, is addressing infrastructure issues and problems and overseeing the development of common standards for vehicle recharging equipment. Through the IWC, the electric utilities, the auto industry, standard-setting organizations, DOE, and regulators are collaborating on the development of these standards. Other key infrastructure issues to be addressed include providing adequate electrical service for battery recharging in private residences, as well as battery recharging facilities in multiple-family dwellings and public areas.

DOE Role in Electric Vehicle Development

Electric Drivetrain Technology - Since the early 1980s, the Department's strategy has been to incrementally improve electric vehicle performance by advancing AC drivetrain technology and integrating it into light-duty vehicles. Our Electric Transaxle (ETX) Program (1984-1990) developed a permanent-magnet, AC motor/transaxle system with advanced inverter, which was successfully demonstrated in a Ford Aerostar van with a sodium-sulfur battery. This development effort, which was cost-shared with Ford and General Electric, recently concluded with the Modular Electric Vehicle Program (MEVP). That program utilized advanced AC-drivetrain technology to develop subsystem components that are applicable to a wide range of vehicles -- from small passenger cars to front- and rear-wheel drive full-size vans. With the economics of mass production, modularization of the electric powertrain across a variety of models and sizes will reduce consumer costs and help support the market entry of electric vehicles. Ford has successfully fabricated nearly fifty of these 75-horsepower electric vehicle powertrains; they are now undergoing extensive testing and engineering evaluation in the Ecostar electric van.

Battery Technology - The possibility of a very large transportation market has spawned an international race to develop an acceptable battery technology for electric vehicles. Laboratories in Western Europe, Japan, and the United States have been engaged in this competition. Research efforts since the mid-1970's in the United States, which have been largely supported by DOE and the electric utility industry, have achieved significant advances in several battery technologies, including advanced lead/acid, nickel/iron, sodium/sulfur, zinc/bromine, lithium/metal sulfide, and iron/air. Despite this progress, however, no single advanced battery technology has emerged as the clear choice for making electric vehicles competitive in the marketplace.

As indicated previously, the Department addressed this limitation by entering into a landmark cooperative, cost-shared agreement with the USABC, which is a partnership among Chrysler, Ford and General Motors. The electric utility industry (represented by EPRI) is also supporting the Consortium through a participation agreement with the partners. The goals of the USABC are to identify the most promising technologies for a viable electric vehicle battery, expedite their development, and establish the capability for a U.S. advanced battery manufacturing industry. The Consortium is working toward specific mid-term and long-term technical objectives for advanced batteries. Current research and development efforts are directed at four advanced battery technologies, two mid-term and two long-term, that show the most promise in meeting these objectives: sodium/sulfur, nickel/metal hydride, lithium/polymer, and lithium (aluminum)/iron disulfide. The USABC has placed R&D contracts with six teams of battery developers, and has signed Cooperative Research and Development Agreements (CRADAs) with several DOE laboratories to develop and test these selected battery technologies. The first prototypes for mid-term batteries have been delivered by the USABC contractors and are currently undergoing rigorous laboratory and field testing. DOE laboratories are also in the process of evaluating the prototype hardware delivered by each contractor to determine the technical feasibility of various long-term batteries. Pilot plant production of at least one mid-term battery is expected in FY 1996-97.

Testing and Standards Development - The specialized equipment of the DOE laboratories provide industry and Government programs with the capability to independently test and evaluate emerging technologies and proof-of-concept vehicles under realistic conditions, both in the laboratory and in the field. The tests are conducted under repeatable and well-defined operating conditions that duplicate or simulate actual vehicle operations and environments. Test results serve to characterize technology performance potential, to independently verify R&D progress, and to provide the critical data needed by other technology developers. Batteries are tested either by subjecting them to the actual electric power demands of electric vehicles on a dynamometer and in test-bed vehicles, or by electrically loading them with simulated, complex driving-cycle power profiles in a controlled laboratory environment over a range of operating temperatures. Advanced electric vehicle drive systems are integrated into vehicles and tested on the track, road, and dynamometer. Typical performance data obtained from vehicle testing include acceleration rate, energy consumption, and range. Auxiliary systems, such as battery chargers, state-of-charge indicators, and battery monitoring and thermal management systems, are also characterized in a realistic vehicle environment. Since the early 1980s, a broad range of state-of-the-art vehicles and batteries have been tested at the Idaho National Engineering Laboratory, the Argonne National Laboratory, and Sandia National

Laboratory. In support of these test and evaluation activities, the DOE laboratories have worked with industry and standard-setting organizations to develop standardized test procedures.

DOE Plans for Energy Storage Technology Development

USABC - The first phase of this cooperative R&D effort will be completed at the end of FY 1995. Contracts initiated during FY 1992-94 will produce at least one mid-term battery system for validation and pilot plant production in 1996-97. The mid-term and long-term battery technologies resulting from this effort will be laboratory and field tested in vehicles. Work is also continuing on battery cost reduction programs (e.g., development of low-cost nickel electrodes), and independent environmental, health, and safety assessments are being performed on the candidate technologies. Cooperative efforts between DOE and the USABC beyond 1995 will focus on the development and commercialization of the long-term battery technologies required to realize the full commercial potential of electric vehicles. The prototype hardware delivered by each industrial developer will undergo extensive laboratory and field evaluations to identify the most promising options for accelerated commercialization. The national laboratories will continue to provide R&D testing and evaluation support to industrial developers and the USABC. This effort is critical to establishing an internationally competitive, advanced electric vehicle battery industry in the United States and achieving significant long-term market success.

High Power Energy Storage - A separate energy storage technology development effort is being planned to support the Partnership for a New Generation of Vehicles (PNGV). It is anticipated that this effort will be a new activity conducted within the existing USABC framework. It would focus on the development of the high-power energy storage systems needed for advanced hybrid and fuel cell vehicles. In addition, a range of exploratory research efforts will continue to improve basic technology; explore promising new batteries, high-energy capacitors, new materials, and cell components; and address the problems that are likely to occur as battery technologies progress through the stages of development toward commercialization.

Lightweight, compact, high-power energy storage devices are key to implementing viable hybrid propulsion systems. Hybrids have been identified as leading candidates to meet the PNGV goal of tripling automobile fuel economy within ten years. A high-power energy storage device could efficiently store engine output while a vehicle is coasting or stopped, and could also store the energy recovered from regenerative braking systems. This stored energy can subsequently be used to supply the acceleration and other peak power needs of the vehicle. Candidate technologies include high-power batteries, ultracapacitors, and flywheels. Cost reduction is critical to the viability of all of these technologies. The DOE program will evaluate promising high-power batteries and flywheel technologies and continue the development of ultracapacitors. Candidate batteries (such as lithium ion batteries) will be targeted. Current flywheel technology will be evaluated to determine baseline performance characteristics. The development and fabrication of carbon-based ultracapacitors and other advanced devices based on enhanced capacitor materials will be continued, and the associated interface electronics will be upgraded. Procedures and facilities for testing and comparatively evaluating high-power energy storage devices will be developed.

DOE Role in Electric Vehicle Introduction

The Department has been involved in several different activities relating to the introduction of electric vehicles into government and private fleets. The Site Operator Program is a joint effort by government, utilities and educational institutions to test and evaluate near-term electric vehicles and their associated infrastructure. Participants are currently operating approximately 120 electric vehicles, and are procuring an additional 50 vehicles this year for testing and evaluation. Vehicles being tested are provided by original equipment manufacturers, as well as small conversion companies such as U.S. Electricar and Solectria. As indicated previously, we are considering modifying the Site Operator program, which would result in sharing the cost of another 100 electric vehicles for testing in FY 1995, in support of the initial phase of *EV America*.

The Department also manages a program which provides incremental costs for the procurement of alternative fueled vehicles for the Federal fleet. Aggressive implementation of this program is a high priority of the Clinton Administration. Under the Federal Fleet acquisition program, DOE is planning to provide funding for 10 to 15 electric vehicles for several different Federal agencies in FY 1994. For FY 1995, we are currently planning to support an expanded introduction of electric vehicles into the agencies' fleets. The number to be procured will, of course, be directly related to the Department's final appropriation.

The Department has been active in coordinating electric and hybrid research, development and deployment activities with other Federal agencies. We formed and sponsor an Interagency Coordination Task Force on Electric and Hybrid Vehicle Technologies. This Task Force consists of representatives from the Departments of Transportation, Defense, Commerce, and Interior, as well as from the Advanced Research Projects Agency (ARPA) of DOD and the National Aeronautics and Space Administration. The Task Force helps keep agencies informed of the other members' activities, and assists in coordination on electric and hybrid vehicle activities. Working toward improved coordination, DOE has recently signed a Memorandum of Understanding with ARPA. The Department has also been coordinating activities with the Federal Transit Administration relative to its Electric Vehicle and Advanced Transportation Systems Program.

The California requirements for zero emission vehicles beginning in 1998 are quite aggressive. For electric vehicles to be competitive, they need to meet purchasers' performance and cost expectations. The battery goals established by the USABC are based on the minimum requirements to achieve customer satisfaction. Although DOE is very encouraged by the advancements being made by the USABC battery developers, none of the batteries currently satisfies the mid-term goals for performance, life, and cost.

Summary

The Department of Energy has been at the forefront of numerous technology advances that are steadily bringing us closer to viable electric vehicles and realization of associated national benefits. On the basis of our record of technical achievements, our sophisticated and specialized laboratory resources, and our history of successful cooperative programs with industry, the Department is in a prime position to support the growing interest in EV technology development. The Department strongly believes that the successful commercialization of electric and hybrid vehicles will contribute greatly to the realization of national energy, environmental, and economic goals, and this Administration is committed to helping achieve success.

Mr. KLEIN. Thank you very much, Mr. Gross, for your very informative testimony.

I would just remind the other witnesses that we do have your statements. They're part of the record, and you may feel free to summarize. I know that we've got a very extensive panel of witnesses, and there are people with time constraints.

Dr. Denman.

Dr. DENMAN. Thank you. Good morning.

Mr. KLEIN. Good morning.

Dr. DENMAN. I'd like to briefly summarize the written testimony I've prepared for the record concerning ARPA's electric and hybrid vehicle technology program. The ARPA electric vehicle and hybrid vehicle technology program was begun in Fiscal Year 1993 and is structured to provide advancements in electric and hybrid vehicle component technologies and to demonstrate these and state-of-the-art components in practical vehicle configurations.

Our overall goal is to develop and demonstrate technologies that can lead to both military and commercial applications. This is very integral with our larger DOD and ARPA dual-use technology strategy for commercial, military, and industry-based integration.

Our military interests lie in advanced combat, as well as support vehicles. For combat vehicles, electric and hybrid technologies offer an opportunity to fundamentally change our design concepts for many vehicles. Payoffs include improved power management for electronics and sensors on those vehicles; lighter power trains for mobility and deployability, particularly power at the drive wheel or drive track; power-intensive survivability enhancements.

We have strived to execute this program in collaboration with other Federal agencies, particularly the Departments of Energy and Transportation. Examples of the collaborative efforts include, first of all, the larger collaboration with the Office of Science and Technology Policy and the White House through the National Science and Technology Council, under the Partnership for New Generation Vehicles, and we are a full player in those discussions.

A recent MOA has been signed with the Department of Energy, which Mr. Gross just referred to, and we have both DOE and DOT participation in our source selection processes for programs. We also are an active player in the Interagency Coordination Task Force that Mr. Gross mentioned, and, as ARPA agents, these agencies are actually executing several of our programs for us.

As a result of our 1993 competition, we were executing these programs through regional consortia to stimulate the widest possible participation and infrastructure development across the country. The six consortia that we are currently supporting are CALSTART in Southern California; the Mid-America Electric Vehicle Consortium, which covers the Midwest region, the Northeast Alternative Vehicle Demonstration Project, which covers New England and the Northeast; the Sacramento Municipal Utility District covering Northern California; the Southern Coalition for Advanced Transportation, which covers the Southeast and Mid-South regions; and the Hawaii Electric Vehicle Demonstration Project.

The key component technologies we are focused on in these programs include power generation, power control, energy storage, although we're very limited in our battery work because we're counting on the U.S. Battery Consortium to, in fact, develop the battery capabilities. We're also looking at alternators and generators and vehicle structures.

In addition to these consortia, we have selected three proposals under the Technology Reinvestment Project. These include a low-cost electric vehicle power train. This is a partnership between Westinghouse and Chrysler, and that agreement, I'm pleased to announce, was signed yesterday by DOE as our agent for this program. We also have an advanced turbo alternator program that DOE will be the agent for, and we have a heavy hybrid vehicle demonstration project for which DOT will be the agent. We are currently managing a competition for execution of our Fiscal Year 1994 program, and we plan to continue this consortia model.

We believe while we've only been underway for a short period of time, we've made some incremental progress, such as rapid battery charging. We have an initial demonstration of a hybrid electric armored personnel carrier, and we've done some low-cost structural concepts.

In conclusion, I believe we have initiated an effective electric and hybrid vehicle program that is both complementary and collaborative with other agencies and will create dual-use capabilities for the military.

I'd be pleased to answer any questions you may have.

[The prepared statement of Dr. Denman follows:]

Statement by

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ELECTRIC AND HYBRID VEHICLE TECHNOLOGY PROGRAM

Before the

SUBCOMMITTEE ON ENERGY

HOUSE SCIENCE, SPACE AND TECHNOLOGY COMMITTEE

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Good morning Madam Chairwoman, Members of the Subcommittee, and staff. I am pleased to appear before you today to outline the Advanced Research Projects Agency's (ARPA) Electric and Hybrid Vehicle Technology program.

Program Overview

The purpose of the program is to conduct research and development on critical electric and hybrid vehicle technologies and to demonstrate their potential for the armed forces and commercial sector. Electric and hybrid vehicle technology has the potential to enable military systems with greater deployability, and significant improvements in mobility while providing the electric power demanded by advanced sensors, emerging weapons, and power-intensive survivability subsystems. This will significantly improve survivability and lethality in future strategically-deployable vehicles. Component technologies being developed apply to both military (combat, tactical, and non-deployable) and commercial electric and hybrid vehicles. This program will develop and integrate vehicle component and infrastructure technologies to accelerate the introduction of advanced electric vehicles for military use and commercial use while enhancing U.S. competitiveness.

This program fits the model of the "dual-use" work currently funded by numerous other ARPA programs. Most importantly, the effort will aid in establishing and maintaining an industrial base that can feed both commercial and military markets. This will enable affordable implementation of electric and hybrid vehicles in both markets.

The technologies being developed in this effort are divided into the following main areas:

- Power Generation, including devices with high-specific power generator sets such as high-speed free-piston engine generators with the capability of using multiple fuels;

- Power Control, including the exploration of high-temperature power switch semiconductors, advanced motor/controller designs, and energy management;

- Energy Storage, including high-energy-density batteries, flywheels, capacitors, and efficient battery charging;

- Electromechanical Conversion, including permanent magnet, alternating current induction, DC brush-commutated, DC brush-homopolar, reluctance, and linear motors; drive train components; and high-efficiency ancillary systems; and

- Vehicle and Component Manufacturing and Safety, including lightweight, high-strength composites and other materials, flexible composite layup, real-time process control, crash test and simulation, dual-use concurrent engineering, and integrated product and process development (IPPD).

Program Coordination and Integration

There is coordination in this and other related ARPA efforts. All our electric and hybrid vehicle efforts are joint programs or complement work that is being done in other agencies and other ARPA efforts. In laying the groundwork for the ARPA electric and hybrid vehicle program, we have worked with the Departments of Energy (DOE) and Transportation (DOT) in implementing the FY 1993 program and we will continue this process as we execute the FY 1994 program. In addition, we are also leveraging other ARPA efforts to ensure that all segments of our research efforts are focused and integrated. For example:

- On June 14, 1994, ARPA and DOE entered into a Memorandum of Understanding to document a commitment to support common interest and objectives in the research, development, and demonstration of transportation and other technologies for military and public benefit.

- ARPA is an active participant in the Interagency Coordination Task Force on Electric and Hybrid Vehicle Technology (Departments of Defense, Energy, Transportation, Commerce and Interior; the National Aeronautics and Space Administration, the National Science Foundation, and the Environmental Protection Agency).

- ARPA's program efforts support the Partnership for a New Generation of Vehicles. This partnership, led by the Office of Science and Technology Policy, has representation from the major automobile manufacturers and numerous government organizations.

- In coordination with the DOE, the Office of the Under Secretary of Defense for Environmental Security, and the Military Departments, ARPA is continuing to explore the national resources and technologies that will reduce our dependence on foreign oil, increase our energy security by diversifying the transportation fuel supply, stimulate the economy, and greatly improve our air quality.

Program Description

The FY 1993 Defense Appropriations Act provided $25 million and the level of funding was increased to $46.25 million in FY 1994 for the continuation of this program. All efforts are competitively selected for funding and require at least a 50/50 cost share from industry participants. However, in FY 1993 the commercial sector voluntarily overmatched the Federal funding to bring the total program to $58 million.

FY 1993 Program

For FY 1993, our program was implemented through six regional consortia--described below--and focused on three primary areas:

1. Develop and demonstrate electric and hybrid vehicles on military bases around the United States - The consortia are employing state-of-the-art electric and hybrid vehicles, in classes ranging from pickup trucks to buses, on military bases within their regions. These vehicles will be replacing existing internal combustion engine vehicles and will be evaluated based on mission performance, reliability, user acceptance, and maintenance and operation costs. Typical missions include flight-crew transportation, base-to-base commuting, and civil engineering routes. The demonstrations have been coordinated with all three Military Services and military transportation personnel are being trained in the use and maintenance of these vehicles. Since the Department of Defense is one of the largest Federal Fleet managers, the military offers a useful application to demonstrate the emerging electric and hybrid vehicle technologies. Many of the daily driving cycles are compatible with electric and hybrid range performance. ARPA also converted an M113 armored personnel carrier to hybrid electric drive. This vehicle is demonstrating enhanced handling and reduced thermal and acoustic signatures.

2. Develop and demonstrate dual-use electric and hybrid vehicles for fleet operations in the commercial sector. In this area, the consortia will demonstrate similar electric and hybrid vehicles being used on the military bases in commercial applications to assess dual-use potential and conduct comparable evaluations. Some innovative applications include the Chattanooga Living Laboratory that is demonstrating advanced technology on in-service electric transit buses, station cars which incorporate electric vehicles for inter-city transportation with metro rail systems, and integrating military developed components into a 40-foot transit bus in Hawaii.

3. Research, develop, and demonstrate advanced components. In this area, component technologies are being pursued that will demonstrate increased efficiency, occupant safety, and energy density as well as reduced weight, size, and cost. Developments are occurring in rapid and inductive

battery chargers, motors; controllers; energy storage devices such as flywheels, capacitors and advanced lead-acid batteries (other battery technology is being accomplished under programs at DOE); auxiliary power units; and heating and air conditioning systems. We are also pursuing work in composites and space frame manufacturing techniques for vehicle bodies that will significantly reduce the weight and coefficient of drag of these vehicles.

We are executing the program through six consortia. This creates a unique partnership between the Government and the private sector, yielding both "competitive cooperation" and "cooperative competition" at a variety of levels. Within each regionally diverse consortia there is both a horizontal and vertical mix of private sector partners engaging in technology dialog. The program conducts national program reviews with the consortia resulting in a rapid increase of the technical knowledge base to a common level to maximize the synergy generated among the individual efforts. The six consortia are led by:

- CALSTART, headquartered in Burbank, California, covers the Southern California region.

- Electricore, also known as the Mid-America Electric Vehicle Consortium, is led from Indianapolis, Indiana and includes the Mid-western region.

- Hawaii Electric Vehicle Demonstration Project (HEVDP) includes all the Hawaiian Islands as well as participants on the mainland and is headquartered in Honolulu, Hawaii.

- Northeast Alternative Vehicle Consortium (NAVC) is led from Boston, Massachusetts and includes all of New England.

- Sacramento Municipal Utility District (SMUD) located in Sacramento, California is working closely with McClellan Air Force Base and organizations in the Northern California region.

- Southern Coalition for Advanced Transportation (SCAT), headquartered in Atlanta, Georgia, covers the largest region from the southeast to Texas.

These consortia involve universities, state and local governments, small businesses, defense contractors, Big-Three automotive suppliers, Federal laboratories, transit agencies, environmental organizations, utilities, and the Military Departments. The regional diversity is an important element of our systems approach since we must have solutions to regional challenges (e.g., climate extremes, terrain, air quality) in order to produce a vehicle design that functions throughout the country.

In addition, the results from three programs selected under the FY 1993 Technology Reinvestment Project (TRP) will support on-going electric and hybrid vehicle technology efforts:

- Westinghouse and Chrysler are working to build and demonstrate a low-cost electric vehicle power train. The DOE is serving as the ARPA agent for this effort.
- We are funding AlliedSignal to build a turbogenerator for use as an auxiliary power unit on an electric vehicle. The DOE is serving as the ARPA agent for this effort.
- TMC, a bus builder in New Mexico, is working with Kaman Electromagnetics, Honeywell, and others to build an advanced 40 foot hybrid electric bus. DOT is serving as the ARPA-agent for this agreement and has given TMC permission to proceed.

FY 1994 Program

To implement the FY 1994 program, a Research Announcement was published in the Commerce Business Daily (CBD) on May 3, 1994. The solicitation, which closes on July 8, is requesting proposals for electric and hybrid vehicle technology from geographically dispersed consortia. As mentioned earlier, the proposals will be selected on the basis of merit in accordance with published evaluation criteria and will require cost sharing by industry.

We are seeking technology advances in component systems and full vehicles that have the potential to be clearly superior in performance and/or cost to those that can be procured without development. However, we are also interested in technologies already "on-the-shelf" that, when enhanced, clearly result in an increased level of performance or a substantial reduction in cost through design modifications, different construction practices, and/or advanced manufacturing techniques.

Technology demonstrations on military and commercial vehicles should be directed toward potential customers. Military use of hybrid electric drive should provide flexibility in the location of drive elements; permit reduction in vehicle silhouette, signature, and volume; and increase mobility and deployability. Commercial use of hybrid and electric drive should provide fuel economy, clean air quality, flexible vehicle and component manufacturing, passenger safety, as well as many of the same benefits obtained in the military use.

Technologies of interest for light duty applications through higher powered military systems are in the areas of power generation, power control, energy storage, electromechanical conversion, and vehicle and component manufacturing and safety.

Accomplishments

Although the Electric and Hybrid Vehicle Program agreements were signed late in CY 1993, there have been several significant accomplishments that will help overcome technology barriers for electric and hybrid vehicles. For example:

- The cooperative effort between the Southern Coalition for Advanced Transportation (SCAT), the Hawaii Electric Vehicle Demonstration Project (HEVDP), and the Northeast Alternative Vehicle Consortium (NAVC) demonstrated rapid recharge of lead-acid batteries in less than 18 minutes on an electric S-10 pickup truck. This test resulted in a new world endurance record of 831 miles traveled in a 24-hour period.

- SCAT conducted a test of the performance of a state-of-the-art diesel powered bus against the Electricore 22-ft electric bus incorporating advanced components developed under the ARPA program. The electric bus ran the quarter mile course 6.5 seconds faster and accelerated 2.5 times faster from 0 to 40 miles per hour than the diesel bus. The electric bus crossed the finish line in excess of 50 miles per hour, emitted no direct emissions and had significantly less noise. In general for an electric bus, fuel costs 12.8 cents per mile less and operations and maintenance is half the cost than for a comparable diesel bus.

- FMC Corporation through SMUD converted a M113 armored personnel carrier to hybrid electric including lead-acid batteries from the GNB Battery Company. This vehicle is being demonstrated by the U.S. Army Tank Automotive Command. Military operations will significantly benefit from the reduced acoustic and thermal signatures and enhanced vehicle handling.

- Under CALSTART, an Aluminum space frame designed to support different body styles for electric vehicle chassis was demonstrated. This technology is anticipated to allow electric vehicles to cost under $18,000 in production runs over 40,000 vehicles. A production run of 40,000 vehicles would use only two weeks of the Aluminum produced by Kaiser. The team included Amerigon, Inc., Kaiser Aluminum and Chemical Corporation, Hughes Power Control Systems, Trojan Battery Company, and Lawrence Livermore National Laboratory.

In conclusion, I believe we have structured an electric and hybrid vehicle technology program that meets all legislative requirements; is thoroughly coordinated with industry, other appropriate federal agencies and the DOD; and will play a significant role in integrating the military and commercial industrial bases. I will be pleased to answer any questions you may have.

Mr. KLEIN. Thank you very much, Dr. Denman. We appreciate very much your important testimony.

And our final witness on this panel is Mr. John Beale.

Mr. BEALE. Thank you, Mr. Chairman, and good morning, members of the subcommittee.

I'm pleased to appear before you today to testify on this very important matter, and, specifically, to talk about the implications of State requirements under the Clean Air Act for zero-emitting vehicles. I believe it is important to first put zero-emission vehicle development in the context of air quality. As you know there has been a great deal of interest, particularly in the California and in the Northeast States, regarding the development and commercialization of zero-emission vehicles. Today more than half of California's 30 million residents live in areas where smog routinely reaches unhealthy levels.

For 30 years we have steadily reduced tailpipe emissions. EPA's certification levels today allow new cars to spew approximately 90 percent, 97 percent less pollutants than cars built a generation ago, but in the long term these significant gains could and probably will be offset because there are more cars on the road today and each one of those cars is being driven more miles. Americans drove over 2 trillion miles last year, nearly triple the number just two decades ago.

As regulators of air quality, we must encourage mass transit, the repair and retirement of unclean cars, and the promotion of vehicles that run on cleaner alternative fuels. Even all of this will not be enough, however, to bring many areas into attainment with the clean air standards.

The Northeast Ozone Transport Commission was authorized under the Clean Air Act Amendments of 1990, based on the recognition that ozone and its precursors are transported throughout the northeastern States and could prevent one or more areas from meeting the ozone air quality standard. The Ozone Transport Region is comprised of the 12 Mid-Atlantic States and northeastern States and the District of Columbia. The Commission itself consists of the governor of each State, or his or her designee; the Administrator of EPA; the Regional Administrators of the affected EPA regions—in this case Regions I, II, and III—and an air quality official representing each State in the region, appointed by the governor. The region has a total population of approximately 68 million people. There are currently 28 Ozone Nonattainment Areas in the region, and they're classified into four categories of nonattainment.

One of the issues that you're most interested, I think, in is our policy on the ZEV sales mandate. EPA's last review of that policy was completed in January of 1993. At that time the Administrator determined that a sales mandate such as exists in California was not necessary for the adoption by California or other states of the California Low Emission Vehicle Program. We are currently reviewing that policy in light of the current OTC/LEV petition which is before us and which is now going through a rulemaking.

States generally have several policy options available to them concerning zero-emission vehicles under the Clean Air Act. First, they could do nothing. There's no requirement that they require these vehicles. Second, they could provide incentives for the sales of zero-emitting vehicles within their borders, including the development of an infrastructure necessary for zero-emitting vehicles. Third, under the Clean Air Act, they could adopt the California low-emitting vehicle program, including the ZEV mandate. And, fourth, in ruling on the OTC petition, EPA will decide whether States may adopt the California program without the ZEV sales mandate.

After an extensive public deliberation process, the OTC voted by a 9-to-4 majority on February 1st of this year to recommend that EPA mandate the more stringent California program throughout the Ozone Transport Region. New Hampshire, Delaware, New Jersey, and Virginia voted against that recommendation.

EPA is in the process of assessing the OTC recommendation to determine whether to approve, disapprove, or partially approve or disapprove it. EPA conducted two days of public hearings on the recommendations in Hartford, Connecticut on May 2 and 3 of this year, and in an effort to permit the broadest-possible public participation, we are in the process of conducting roundtable meetings concerning the recommendation throughout the region. The first roundtable meeting was held in Philadelphia on June 8; the second was held in Durham, New Hampshire on June 23, and the final one will take place in New York City on July 13.

EPA is required to make its recommendation on the—its determination, rather, on the recommendation within nine months of the receipt of the petition under the Clean Air Act. The final decision regarding the recommendation will be made by November 10 of this year.

In an effort to provide the subcommittee with a ball park estimate of zero-emission vehicles expected to be sold in the OTC, if a sales mandate were included as part of the OTC/LEV program, the NESCAUM, which you referred to earlier, Mr. Chairman, has estimated that, by the year 2003, 215,000 electric vehicles would be sold in the NESCAUM region. By 2005, nearly 1 million vehicles would be sold in that same region.

The State of New York, which you referred to earlier also, Mr. Chairman, which has adopted a sales, a ZEV sales mandate, estimates that by 2003 roughly 100,000 electric vehicles would be sold per year in New York State.

EPA believes that any decision on the petition itself raises substantial and difficult questions that are directly linked to the northeastern States' overall strategy for ozone attainment. In other words, we need to consider the emission reductions the region needs and what measures can achieve those reductions. Regardless of the final disposition of the petition, it is clear that additional measures will be necessary if the region is to reach and maintain attainment. Where and how those measures are initiated will be considered in the course of responding to this petition. Through EPA's review process, the public hearings, and the roundtable meetings, we hope to facilitate a decision that will resolve many issues presented by the petition. We hope to make a decision which is not only broadly supported by the citizens of the Northeast, but one that is workable, efficient, and will move the region closer to the attainment of clean, healthy air.

Mr. Chairman, no single technology has had a more profound effect on our lives or on our collective psyche than the automobile. The ability to go where we want when we want has come to define a freedom and a possibility that is uniquely American. As we at EPA seek to reduce the emissions from automobiles, we are always mindful of the degree to which physical mobility is linked with social mobility and personal freedom. While automobiles are far cleaner today than they were 20 years ago, light-duty cars and trucks remain one of the largest sources of air-borne pollution that we face.

Some have suggested that we must decide—or, rather, that we must make a choice in this Nation between clean cars and clean air. We at EPA reject the legitimacy of that choice. The goal of producing a truly zero-emission vehicle is essential in that it reveals the fallacy of the choice between public mobility and public health.

Thank you for the opportunity of testifying this morning, and I'll be pleased to answer any questions you may have.

[The prepared statement of Mr. Beale follows:]

TESTIMONY OF JOHN BEALE
DEPUTY DIRECTOR, OFFICE OF POLICY ANALYSIS AND REVIEW
OFFICE OF AIR AND RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
SUBCOMMITTEE ON ENERGY
OF THE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

JUNE 30, 1994

Good morning Mr. Chairman and members of the Subcommittee. I am pleased to appear before you today to testify on electric vehicles and advanced battery research and development, and specifically, on the implications of state requirements under the Clean Air Act for zero-emission vehicle (ZEV) development.

I believe it is important to first put zero-emission vehicle development in the context of air quality. As you know, there has been a great deal of interest, particularly in California, regarding the development and commercialization of zero-emission vehicles. Today, more than half of California's 30 million residents live in areas where smog routinely reaches unhealthy levels and cars cause half of the pollution. For thirty years, we have steadily reduced tailpipe emissions. EPA's certification levels allow today's new cars to spew 97% less pollutants than cars built a generation ago. But in the long-term, these significant gains could be offset because there are more cars on the road and the total miles driven are increasing. Americans drove 2.147 trillion miles last year, nearly triple the number two decades ago. As regulators of air quality, we must encourage mass transit, the repair and retirement of unclean cars, and the promotion of vehicles that run on cleaner alternative fuels. Even all this will not be enough to bring many areas into attainment of clean air standards.

The Northeast Ozone Transport Commission (OTC) was authorized under the Clean Air Act Amendments of 1990 based on the recognition that ozone and ozone precursors transported throughout the Northeastern states could prevent one or more areas from meeting the ozone air quality standard. The Ozone Transport Region (OTR) is comprised of the twelve mid-Atlantic and Northeastern states, and the District of Columbia. The Ozone Transport Commission consists of the governor of each state or his/her designee, the Administrator of the EPA, the Regional Administrators for the affected EPA regions (Regions 1, 2, and 3), and an air quality official representing each state in the region, appointed by the governor.

The OTR has a total population of 68 million people. There are currently 28 ozone nonattainment areas in the Ozone Transport Region. Nonattainment areas are classified into four categories with associated attainment dates: 12 designated as marginal ozone nonattainment areas (1993), 7 as moderate (1996), six as serious (1999) and 3 as severe ozone nonattainment areas (2005 or 2007).

EPA's policy regarding the ZEV sales mandate was last reviewed in January 1993 when the Administrator determined that a sales mandate was not necessary for the adoption of the California Low-Emission Vehicle (LEV) Program. EPA is currently reviewing this policy in light of the OTC/LEV petition.

States have several policy options concerning zero emission vehicles (ZEVs). First, they could no nothing. Second, they could provide incentives for the sales of ZEVs within their borders, including the development of the infrastructure necessary for ZEVs. Third, under the Clean Air Act, they could adopt the California LEV Program, including the ZEV sales mandate. Fourth, in ruling on the OTC petition, EPA will decide whether states may adopt the California

LEV Program without the ZEV sales mandate (which would encourage but not require the development of ZEVs).

After an extensive public deliberation process, the OTC voted by a 9 to 4 majority on February 1, 1994 to recommend that EPA mandate the more stringent California Low-Emission Vehicle (LEV) Program throughout the Ozone Transport Region. New Hampshire, Delaware New Jersey and Virginia voted against the recommendation.

EPA is in the process of assessing the OTC/LEV recommendation to determine whether to approve, disapprove or partially approve or disapprove it. EPA conducted two days of public hearings on the OTC recommendation in Hartford, Connecticut on May 2 and 3, 1994. In an effort to permit the broadest participation by the public within the OTR, EPA is in the process of conducting public round table meetings concerning the OTC/LEV recommendation throughout the Region. The first meeting was held in Philadelphia on June 8, the second in Durham, New Hampshire on June 23, and the final round table meeting will take place in New York City on July 13, 1994. EPA is required to make its determination on the OTC recommendation within nine months of receipt of the petition under the Clean Air Act. A final decision regarding the OTC recommendation will be made by November 10, 1994.

The LEV program recommended by the OTC would apply to 1999 and subsequent model year passenger cars and light-duty trucks in the OTR. The OTC/LEV program would establish four categories of vehicles: transitional low-emission vehicles (TLEVs); low-emission vehicles (LEVs); ultra-low emission vehicles (ULEVs); and zero-emission vehicles (ZEVs). Each vehicle category has specific exhaust emission certification standards for hydrocarbons (expressed in "non-methane organic gases" or "NMOG"), carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM) and formaldehyde (HCHO).

The OTC/LEV program would also establish a NMOG "fleet average" requirement that, for passenger cars and small light-duty trucks (LDTs), would decline from a value of 0.113 gpm in 1999 to 0.062 gpm in 2003 and later years. Manufacturers would be free to decide the mix of vehicle categories they would produce to meet the NMOG fleet average, except that if EPA determines that the Clean Air Act requires the OTC/LEV program to include the ZEV sales mandate, then the manufacturers would be required to include in the vehicle fleet a certain percentage of ZEVs per model year. (The OTC recommendation, barring an EPA determination that section 177 requires the adoption of a ZEV mandate, leaves the decision to adopt a ZEV mandate to the individual states).

The OTC explicitly excluded California reformulated gasoline requirements from its recommendation. The OTC/LEV program would be enforced by the OTC states.

In an effort to provide the Subcommittee with a ballpark estimate of the number of zero-emission vehicles expected to be sold in the OTC, if a sales mandate were included as part of the OTC/LEV program, NESCAUM (Northeast States for Coordinated Air Use Management) estimates that by the year 2003, 215,000 electric vehicles would be sold. By 2005, nearly one million electric vehicles would be sold in the NESCAUM region. The NESCAUM area does not include the entire OTR. The State of New York, which has adopted a ZEV sales mandate, estimates that by 2003 roughly 100,000 electric vehicles would be sold per year.

EPA believes that any decision on the petition raises substantial and difficult questions that are directly linked to the Northeastern States' overall strategy for attainment of the ozone standard. In other words, we need to consider what emissions reductions the region needs and what measures can achieve those reductions. Regardless of the final disposition of the OTC petition, it is clear that additional measures will be necessary if the region is to reach and maintain attainment. Where and how those measures are initiated will be considered in the course of responding to the petition.

Through EPA's review process -- the public hearings, the round table meetings -- we hope to facilitate a decision which will resolve the issues presented by the petition. We hope to make a decision which is not only broadly supported by the citizens of the Northeast, but one that is workable, efficient and that will move the region closer to attainment of clean, healthy, air.

Thank you for the opportunity to testify this morning. I will be pleased to respond to any questions you may have.

Mr. KLEIN. I thank you, Mr. Beale, and I thank the entire panel for their very, very illuminating testimony.

Mr. Gross, you mentioned that you—that it was your best estimate that heavy production of EV vehicles would come somewhere around 2000. Did I understand you correctly?

Mr. GROSS. Mr. Chairman, let me clarify. I was referring there to electric vehicles that would incorporate battery technology that is resulting from the current U.S. Advanced Battery Consortium activity. So if we're looking at mid-term batteries, the battery that meets the mid-term objectives going into initial pilot production and long-term testing in 1996, we're looking at somewhere around the year 2000 for full-scale production of those batteries.

Mr. KLEIN. Well, what I'm trying to do is to get straight in my head to reconcile on the one hand the California mandate and on the other hand the progress toward attaining that California mandate. Are we talking about apples and apples? The 2-percent vehicles referred to in the California mandate, are they the same kind of vehicles that you're referring to in your testimony?

Mr. GROSS. The vehicles that would satisfy the California mandate in 1998 and in the early couple of years of that mandate, we would not expect many of those to have battery technology that is currently still in the development stage because of the lead times associated with long-term testing and the challenges associated with scaling up production facilities.

Now maybe it would have to be met——

Mr. KLEIN. So you're talking——

Mr. GROSS [continuing]. With vehicles which have current or near-term lead acid battery technology that most likely would provide the propulsion mechanism for the vehicles that would be available in 1998.

Mr. KLEIN. Well, let me ask you this: how many vehicles are represented by a sale of 2 percent in 1998 in California?

Mr. GROSS. My understanding is that that number is somewhere around 35,000.

Mr. KLEIN. Around 35,000 from California alone? If other States would adopt the California standard, obviously, that would increase it substantially.

Mr. GROSS. That's correct.

Mr. KLEIN. Is there any indication as to manufacturers' ability or programming to achieve that state, that volume of production by 1998?

Mr. GROSS. I think most everyone recognizes that achieving that requirement is going to be a stretch for all of the manufacturers working together. We would expect, with that mandate on the books and staying on the books, that it would be met, as I indicated, depending primarily on lead acid battery technology, hopefully, with some additional improvements.

And some of the organizations which will testify today will certainly talk about some of the possible improvements in batteries, as well as drivetrain technology, that could have a shot at being incorporated over the next few years. But we will still have a situation, probably, where those vehicles are going to have some fairly hefty incremental costs. There are going to have to be some issues with respect to reliability and warranties perhaps worked out, and

I suspect we'll have some very creative—the opportunity exists for some creative linkages of fast-moving small companies and the large automotive producers, which will, in fact, have to meet the mandates.

Mr. KLEIN. I don't know whether it was Dr. Denman or Mr. Beale, but one of you referred to some estimates of production of vehicles by the year 2003 and a larger number by a somewhat later year. Was it Mr. Denman? Mr. Beale?

Are those estimates, are they based upon mandates and the numbers that would be necessary to achieve the goals represented by the mandates?

Mr. BEALE. Yes, Mr. Chairman. The numbers which I gave you come from NESCAUM in one case and from the State of New York in the other, and they are based upon—it's my understanding they are based upon the same sales mandate percentages and years as the California sales mandate.

Mr. KLEIN. Let me ask you, all three of you, I know that some of the consortia are—involve partnerships with the three major automakers. Is it your view that the major automakers are making the most vigorous possible effort to achieve the goals that we would like to achieve? I'll put all three of you on the spot.

Mr. GROSS. Well, I'd like to comment on that. We certainly have, as I testified and as you know, a substantial partnership with the U.S. Advanced Battery Consortium. We are excited about some of the early results that are coming from that, a more focused program for battery development in some of the competition among the battery developers.

I'd like to point out that it's not just the major automakers that are involved in this. In fact, the work is being done and the money is being spent by the battery developers who are under contract to the consortium. I can assure you that those organizations are very aggressive and they're very strongly supported by the major automakers in their aggressiveness to attempt to make these breakthroughs.

Mr. KLEIN. So it is your view, then, that the major automakers are proceeding aggressively to achieve those goals?

Mr. GROSS. Absolutely, and looking ahead, you'll undoubtedly hear more about the GM-Ovonic agreement. We're anticipating that that will help in speeding up the ability to move through the manufacturing development phase and perhaps meet or beat the years that I forecast a few minutes ago.

Mr. KLEIN. Dr. Denman, do you share those views?

Dr. DENMAN. Well, let me try to answer it this way: this is experience mainly gained from the National Science and Technology Council group that Mary Good from the Department of Commerce chairs, as we've worked with this new generation—Partnership for a New Generation Vehicle. What I sense is that the Big Three are, in fact, accelerating their investments, accelerating their commitments, and whether I would call it aggressive at this point, I know it's accelerating and I think that's good news.

Mr. KLEIN. Mr. Beale, what about you? We go from aggressive to accelerating. What's your opinion?

Mr. BEALE. Well, I appreciate the opportunity to respond to that question, Mr. Chairman.

I think the answer to that question has to depend partly on one's perspective. So I'm going to weasel a little bit for you here.

It's very clear that the Big Three auto companies are making major research and development efforts in this area, as outlined by Mr. Gross. And, particularly, at the technical level, there's a lot of very, very good work going on. I'm sure you'll hear about some of that this afternoon.

It's also true, however, that they have some very serious concerns about, will the public accept the vehicles that they feel they'll be able to produce, for example, in 1998? Will it meet the needs that the public has? And will the battery capacity be available? So they are also very vocal about those concerns and they share those with us all the time.

I think it's fair to say that they are making major efforts in these areas. I think, though, that other people might have the perspective that they could be doing a lot more in putting more energy and effort into it. I'm not in a position to really evaluate that. We see that they are doing a lot of work, and we also hear the comments of folks who feel that they could be doing more.

Mr. KLEIN. Thank you.

Mr. Fawell, do you have some questions?

Mr. FAWELL. Well, I—just commenting on this last question, we certainly are talking about a great social revolution, as well as the production of vehicles that are going to meet that 1998 deadline. I, for one, have a lot of doubt that those deadlines are realistic, considering that even today with the standard car, new car, it takes an awful lot of investment, an awful lot of time, and we have all the infrastructure there. We need here the infrastructure and so very, very much more, that I have a lot of question in my mind if the—about these mandates, although it may well be that if it's 35,000 cars that would have to meet these standards by 1998, we might be able to do that through governmental purchases or some companies that use fleets, taxicabs, and things of that sort, and maybe in that sense it's not quite as unrealistic.

I guess the only question I would have of all of you or any one of you is: in the last year has there been the progress, in your view, that you had envisioned a year ago, when we received testimony on this subject? Have we—has the progress been thrilling, exciting, really going, or has it been, well, you know, we're moving; it's tough? How would you classify progress?

Mr. GROSS. Well, I'd certainly comment that we're pretty enthusiastic about the progress that's being made, and I've indicated that the first contract under the USABC with the Ovonic Battery Company, awarded in, I think, December of 1992, has provided the basis for a very encouraging outlook. That battery is being tested in national laboratories and other places, but it's already been used, as has been mentioned, in the vehicle which set the distance record in the Tour de Sol and in the vehicle which finished first in this year's Phoenix 500. And so there's kind of a line that's developing in terms of moving to news which is exciting fairly quickly after the laboratory work is done.

Mr. FAWELL. Would you be satisfied—would you say, "I'm more than satisfied," from a year ago in May when we had hearings in regard to this subject matter, "I'm more than satisfied in the progress we have made. We're right online or ahead of what I would expect." Would it be—would that be fair to say?

Mr. GROSS. Well, I don't know that you can ever say that it's as fast as you'd like in your best-case scenario, but we're certainly very, very satisfied that we're getting some good results.

On the deployment front, I think we're sufficiently encouraged that we are working hard with the utilities, primarily through their organizations that are working on EV America, to see if we can get a better utilization of the Federal fleet vehicles, in combination with other fleet vehicles, to have a combined demonstration program that can help more quickly drive the cost down for the state-of-the-art technology by combining and ensuring vendors of minimum orders for electric vehicles.

So in the past year, our view has changed with respect to our willingness and comfort level with respect to moving more aggressively under Title VI of the Energy Policy Act, for example, in directing some of our activities toward demonstration and laying the ground work for that.

Mr. FAWELL. Dr. Denman.

Dr. DENMAN. Yes, I certainly agree with that, but I think something we all have to keep our eye on is the fact that the marketplace is going to drive this, whether it's an affordable military vehicle or whether it's a low-cost commercial—you know, with reasonable performance in the commercial sector. I think a lot of exciting progress is being made and I agree with you on that point, but I think we also have a very long way to go. I do not believe that there are any silver bullets or miracles about to happen from the technology community, and we're going to have to grind this out.

It's not just a battery problem. It's a motor; it's a power controller, and structures. So it's going to take a systems approach, I believe, to really make, if you will, the breakthrough. It's not going to come from a single point. The battery is exciting. We're doing some exciting things in power controllers that, by the way, today cost more than the batteries. So we have to pay attention to some of those questions. Particularly, if you're handling high powers like for military vehicles, the power controllers are very expensive. So we have to attack all fronts of this, then. I think we have to be careful we don't over-promise what's going to happen from the technology community. And, by the way, after we invent it, we have to figure out how to make it low cost, and that's just as hard.

Mr. FAWELL. And then convince the people to buy it.

Mr. BEALE. I would just add one point. I think Dr. Denman's point is very critical about the cost of these vehicles. Right now there's quite a range and there's quite a bit of debate about how much these electric vehicles will cost. The State of California is estimating that they will be approximately the same as a conventional car, and the auto manufacturers are telling us they could be as much as $20,000 more than a conventional car.

One of the areas in which progress is being made, in addition to the technology, is there's a lot of creative thinking going on in how to kind of structure the organization of this market. I'll give you one example.

The auto companies tell us that the largest bulk of that cost differential is going to be in the batteries, and there's a lot of thinking going on about, instead of having people buy the batteries, let them rent or lease the batteries, which could significantly lower the cost to the consumer, and there's opportunities there to have utilities help subsidize that. So there's a whole—in addition to the technology and thinking about the hardware, there's a whole lot of thinking going on about the software, about how you can deliver these vehicles in a reasonably cost-effective way to people, and we're very excited about that.

Mr. KLEIN. Thank you very much.

And now I'd like to recognize the very distinguished gentleman from Michigan, Mr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman.

My questions would be a little different. I'd like to get down to some fundamentals here, perhaps to help my understanding.

First of all, it seems to me that you've done a good job of discussing the technology. You've alluded to some of the cost problems. I'm wondering what is being done in terms of basic science as it relates to this. Obviously, one of the biggest problems is improving the energy density of the devices, and particularly the energy density per unit weight of the storage device. I'm totally unimpressed with batteries, but recognize that's our immediate alternative. The lead acid battery is a particular problem. Nickel hydride may be a good alternative, but, even so, a battery is a large, heavy, cumbersome device in general. We've talked about flywheels. We've talked about supercapacitors. All of these are just—they're using existing science that's been around for 100 years, and I'm asking a couple of questions.

First of all, where do you see the direction going in improving the energy density of a storage device? And, secondly, do you see anything being done or any promise in totally different approaches which will take longer to develop and reach the market, but really are essential if we're going to get anywhere? For example, you can store a lot more energy in phase changes than you can do in a lot of other things. They'd be difficult devices to build, but, certainly, that's an example of the sort of thing I'm talking about.

My question is addressed to each and all of you, and I'd be interested in what is happening in your agencies that would give some indication, or even outside of your agencies in the private sector. Dr. Denman.

Dr. DENMAN. We don't—we, certainly, at ARPA do not have a highly-focused basic research program on electric vehicles. I think that, first of all, would be inappropriate. I believe other agencies should be doing that.

But I do think there are some technologies that are sort of moving out of the basic and into the applied. For example, in the fuel cell area, while I'm certainly not going to sit here today and promise you a fuel cell that's going to be in a car in five years or even ten years, but that's an attractive alternative to batteries and it, obviously, provides the emission control issues.

There is some interesting work in electronics. I keep mentioning the power control problem. You must understand I'm coming from basically a hybrid vehicle perspective for the Department of Defense, because full electric for most of—certainly for our combat vehicles just doesn't make any sense. There's no place to plug it in on the battlefield.

But the efficiency and energy-use efficiency of hybrids are very attractive and about the same—we can argue 5 percent or so differences, but they're about the same as full electric in terms of energy efficiency. They'll maybe apply to the same problems with respect to emissions; they are different problems. One is localized emissions and one is distributed emissions.

But I think in a lot of our investments in high-temperature electronics—we're doing some exciting basic work in silicon carbide as—instead of regular silicon, we use an electronics, as you know, in your computer, using silicon carbide as the active electronic medium, and it's a high-temperature material. So you can run the silicon carbide much hotter, which is a power—any time you're dealing with significant power, that's a major issue.

So those sorts of things I think are going on at the basic level.

Mr. EHLERS. Thank you.

Mr. Gross.

Mr. GROSS. Let me mention that in the handout that I provided the last page lists some of the USABC criteria for the mid-term and long-term batteries. On energy density in watt hours per liter, the mid-term goal is 135. That's over twice the current battery technology capability, with a long-term goal at 300 watt hours per liter. In specific energy, similarly, significant increases are needed just to get to the mid-term goals. So there is work going on among the developers being funded in the program, work on materials and on chemistry and on design of batteries which are going to have to be done in order to meet these goals.

But, in addition to that, we also support this year a bit over $4 million which is for exploratory technology research. This is work that is reviewed in the context of the USABC, does not go through the USABC funding mechanism, but is basic research—supporting more basic research to understand the chemistry associated with some of the battery types that are felt to have the most promise and which are included in the contracts.

Mr. EHLERS. Okay, but I don't hear in either answer any really innovative approaches being discussed. It's basically technological improvement over what's already out there. Is that a fair characterization?

Dr. DENMAN. I think I wouldn't argue with you at all on that point, but there are things down at the basic science level. You have to recognize for batteries, you know, Mother Nature dealt us a deck of cards called the periodic table, and there's only certain materials that will come together to build a battery. So you're dealing with fundamental limitations here, and——

Mr. EHLERS. That's right. That's why I think batteries are of limited usefulness in electric vehicles.

Dr. DENMAN. But, you know, for example, we've done some exciting work for electronic applications, not for power applications, in the lithium polymer battery. And as you try to move that to power, we're running into some very fundamental problems. You can't extract the power fast enough out of the battery because of the internal resistance. But that's a factor of six or so better than lead acid.

So there are some—and that's—if we could get a factor of six over lead acid, believe me, we would have very exciting electric vehicles.

But there are some tough problems that have to be dealt with, and there are other very exciting battery concepts out there. Most of them have very serious cost barriers and safety and environmental, disposal, you know, recycling issues.

So, no, I don't, in batteries particularly, I don't forecast any major invention because we're dealing with the periodic table, and we understand the periodic table and what we will do in batteries. So it becomes a matter of either working cost or working some fundamental internal structure problems in the battery, and there's quite a bit of investment going on in the battery consortium and across the government. NSF has some fundamental work in this area, and so does ARPA and the military departments as well.

Mr. KLEIN. My friend from Michigan, Mr. Ehlers, I think raises some very, very important questions. Unfortunately, we're not going to answer all of the questions in this hearing, but I think the bottom line—and I think all of us, I speak not only for those on the panel, but, indeed, for the entire Nation, I think that we all understand that one way or another, through some technology, we've got to achieve the goal of having vehicles that will be powered by a source that reduces emissions, reduces dependence upon foreign oil, and that is cost-effective. And American ingenuity has achieved some marvelous things over the years in so many other areas; I'm confident that with the right focus and incentives American ingenuity can achieve those goals in this area as well.

We do have a second panel, and I know that there are time constraints on all of the witnesses. However, before I close, I did want to get just a bit of very precise factual information from Dr. Denman, and then we would move on to the second panel.

Dr. Denman, ARPA has received funding in Fiscal Year 1993 and 1994 for electric vehicle development. The Fiscal Year 1993 involves the six consortia mentioned in your testimony. What is the time frame for deliverables of those contracts and what is the time frame for Fiscal Year 1994 activities?

Dr. DENMAN. With respect to the deliverables on the current contracts with consortiums—and many of these actually are cooperative agreements or agreements with a consortium and not formal contracts. They have the same effect, of course, of transferring money. I can't cite song and verse, but I'd be happy to answer that question for the record in terms of what deliverables when. That money is being spent, basically, through Fiscal Year 1994, and our 1994 money, proposals I believe are due in a few weeks for the 1994 programs. We will be making those decisions in about six weeks from now in terms of source selection on those programs, and then we will write the contracts or agreements.

Mr. KLEIN. Okay, can we get some assurance from you, Dr. Denman—we do have a few questions for the record—that perhaps we could get a response, say, by the time Congress reconvenes on July 12?

Dr. DENMAN. I'm sure that's possible if I get the questions——

Mr. KLEIN. We'll have the questions out to you immediately, and that will give us the opportunity—yes, we'll have all of those questions out to you this afternoon, and if you will accommodate by getting them back to us, that will enable us to complete the record for the hearing.

Dr. DENMAN. We'll do our best.

Mr. KLEIN. I want to thank the witnesses again for their most informative testimony, and at this point we shall move on to panel two.

Well, gentlemen, thank you.

Our second panel consists of people who are in industry and directly associated with the development of battery technology. And the witnesses include Mr. John F. Williams of the GM Electric Vehicle Program, and chairman of the U.S. Advanced Battery Consortium; Mr. Stanford R. Ovshinsky, president of Energy Conversion Devices, Inc., of Michigan; Mr. James D. Worden, chief executive officer of Solectria Corporation of Arlington, Massachusetts; and Mr. Michael J. Bradley, the executive director of the Northeast States for Coordinated Air Use Management, located in Boston, Massachusetts.

Gentlemen, I'll—as I did with the other panel, I'm going to ask you to testify and call upon you in the order in which I introduce you, but if there is among yourselves an agreement that there would be a better order, we'll certainly be happy to accommodate that. Any particular feeling on that subject? If not, we will proceed with the witnesses in that order. And, again, we will defer questions until after all four witnesses have testified.

Our first witness, Mr. John Williams.

STATEMENT OF JOHN F. WILLIAMS, GM ELECTRIC VEHICLE PROGRAM, GENERAL MOTORS CORP., TROY, MI, AND CHAIRMAN, U.S. ADVANCED BATTERY CONSORTIUM; STANFORD R. OVSHINSKY, PRESIDENT, ENERGY CONVERSION DEVICES, INC., TROY, MI; JAMES D. WORDEN, CHIEF EXECUTIVE OFFICER, SOLECTRIA CORP., ARLINGTON, MA; AND MICHAEL J. BRADLEY, EXECUTIVE DIRECTOR, NORTHEAST STATES FOR COORDINATED AIR USE MANAGEMENT, BOSTON, MA

Mr. WILLIAMS. Thank you, Mr. Chairman, and I will summarize.

I'm pleased to be here representing my colleagues at the USABC. We share your sense of urgency, and we are, in fact, committing our working lives to developing advanced batteries for electric vehicles. We're trying to achieve our goals as quickly as possible. While advanced battery development is very challenging, very high risk, the results to date have been encouraging.

USABC was formed in 1991 as a partnership of Chrysler, Ford, and General Motors, working with the electric utility industry through the Electric Power Research Institute and with the Department of Energy. The support and cooperation of the DOE is key to achieving our goals. Not only is the DOE directly involved in the work of USABC; they continue to support valuable, longer-range battery research that could result in development important to the future work of the USABC.

The purpose of the USABC is to develop for commercialization advanced battery systems that will provide increased range and improved performance for electric vehicles in the latter part of the 1990s. USABC has been successful in focusing the battery industry on electric vehicle requirements, both technical and commercial.

We've taken a top-down systems approach to developing clear requirements for both mid-term and long-term batteries.

The mid-term specifications represent a substantial improvement over currently-available batteries. The long-term specifications were developed to enable electric vehicles to ultimately compete with gasoline vehicles.

USABC has based our development and our funding decisions on the results of objective hardware evaluations performed in the DOE national laboratories. These tests have been invaluable in determining the true capability and state of development of many advanced batteries. The result is that we now have a general agreement on which are the most promising technologies for the future.

An understanding of what happens in the battery development process helps to characterize the state of development of the technology today. Battery development is a scale-up process from electrochemistry to cells, to modules, to full-sized packs. It's a process of building confidence steadily and progressing to the next step as quickly as success is achieved.

This scale-up process is challenging because it requires balancing and optimizing of competing and conflicting goals. Difficult tradeoffs must be made to optimize energy, power, cycle life cost, and many other parameters. Tradeoffs made to improve one parameter sometimes compromise another parameter, and the resulting process is often two steps forward and one step back.

A full-size battery pack capable of powering an electric vehicle contains hundreds, or even thousands, of individual battery cells. Full-size packs can be expected to exhibit application problems not apparent at the cell level or the module level. Additionally, the battery process for development must be in sync with the process for vehicle development. For example, 1998 vehicle programs are now in the early stages of the product development process and battery systems for these vehicles are being selected and integrated into the vehicle designs now. So battery systems that are currently still in the scale-up process are not candidates for these vehicle programs due to the uncertainty and the high risk of their further development. However, battery systems that have completed scale-up and have met all the criteria at the full- size pack level are candidates and can be considered relative to other viable alternatives.

So where are we today? We made some very encouraging progress. All USABC developers are producing actual batteries in hardware that is under test at the national labs. For the mid-term batteries, most work is at the cell or module level, and the hardware is demonstrating very good energy relative to currently-available batteries. Some full-size packs have been produced, but none have achieved all of the mid-term criteria. To meet all the mid-term criteria concurrently will require further development, refinement, and possibly fundamental chemistry changes focused at improved cycle life and durability performance.

As mentioned earlier, perhaps the biggest challenge of all is that at this point it's not clear how we will achieve our cost goals. Early commercialization will be costly, and funding support may be necessary to offset capitalization of manufacturing facilities and the cost of the resulting batteries in the start-up phase. To achieve true commercial viability, battery costs must ultimately be reduced to the level where the process is self-sustaining.

The immediate work to be undertaken now is the development to achieve the cost and performance criteria. The current USABC estimate is that packs, the first packs, meeting all mid-term criteria will be achieved in mid-1996. At that point it will be appropriate to build a number of packs to verify cycle life, safety, and quality on a statistical basis.

Concurrently, the commercialization process to design and construct a pilot facility could begin. This would be a low-volume facility to develop low-cost battery manufacturing processes and produce initial volumes. Taking a technology through scale-up and into pilot commercialization is costly in terms of both staffing and funding. The USABC is fostering competitive development at this time, but is planning to focus our development portfolio on fewer contracts in the future.

For the mid-term technologies, the next six to twelve months will be used to identify the most promising developments warranting enhanced support, and discontinuing efforts on those that do not live up to their promise. The most encouraging development has been the formation of GM-Ovonic, a new joint venture formed by private industry to accelerate commercialization of one of the USABC mid-term technologies. This venture would not have been possible without the USABC, and the ultimate success of the venture is highly dependent on continued development by the USABC to advance the technology to full commercial viability.

The USABC and CARB are committed to a close working relationship with open communication. And to that end, CARB has accepted a USABC invitation to join the USABC process as an observer at our monthly meetings of the technical committee.

Regarding future plans, the first phase of the USABC has the goals of commercializing a mid-term battery and demonstrating feasibility of a long-term battery. A successful program will require a sustained commitment by all stakeholders to the original goals and the original funding of $262 million.

Beyond this, the second phase of USABC will continue development of the most promising longterm technologies which will enable electric transportation to ultimately to be competitive with gasoline transportation. Also, the USABC and the Partnership for New Generation of Vehicles have agreed to integrate their development as much as possible. USABC will use its existing structures and processes to manage the development of electrochemical batteries and also capacitors for PNGV. Further opportunities for cooperation and integration are being explored.

In conclusion, I offer my observation that the challenge facing us collectively is one of teamwork as much as technology, teamwork between competing automobile manufacturers, teamwork between vehicle manufacturers and battery manufacturers, teamwork between industry and government. We've already accomplished more together than any of us could have accomplished separately, and further cooperation is the key to our ongoing success. USABC looks forward to providing continued leadership toward our mutual goal of developing advanced batteries for commercially-viable electric vehicles.

Thank you.

[The prepared statement of Mr. Williams follows:]

Statement of

John F. Williams

Chair

United States Advanced Battery Consortium

Submitted to the

Subcommittee on Energy

Committee on Science, Space and Technology

United States House of Representatives

June 30, 1994

Washington D.C.

Good Morning, my name is John Williams. I'm employed by the General Motors Electric Vehicles Platform and I'm serving during 1994 as Chair of the United States Advanced Battery Consortium. I'm pleased to be here representing my colleagues at the USABC. We're committing our working lives to developing advanced batteries for electric vehicles and we're striving to achieve our goals as quickly as possible. While advanced battery development is very challenging and high risk, the results to date have been encouraging. My purpose today is to provide an update on USABC accomplishments, as well as an assessment of the status of battery technology, and a projection of future timing.

USABC Background

The USABC was formed in 1991 as a partnership of Chrysler, Ford and General Motors, working with the electric utility industry through the Electric Power Research Institute and with the U.S. Department of Energy. The support and cooperation of the DOE is key to achieving USABC goals. Not only is DOE directly involved with the work of USABC, they continue to support valuable longer range battery research that could result in development important to the future work of USABC.

The purpose of the USABC is:

> TO DEVELOP FOR COMMERCIALIZATION ADVANCED BATTERY SYSTEMS THAT WILL PROVIDE INCREASED RANGE AND IMPROVED PERFORMANCE FOR ELECTRIC VEHICLES IN THE LATTER PART OF THE 1990s.

The USABC continues to focus on any and all advanced battery technologies that can achieve this purpose, i.e., technologies with both technical and commercial feasibility. Funding for the first phase of USABC is $262 million, shared equally between industry and government.

The USABC has been successful in focusing the battery industry on electric vehicle requirements, both technical and commercial. We've taken a "top-down" systems approach to developing clear requirements and documenting them in the technical specifications for mid-term and long-term batteries. Mid-term specifications represent a substantial improvement over currently available batteries. These specifications were developed to be challenging, but achievable in the 1990s. Long-term specifications were developed to enable electric vehicles to ultimately compete with gasoline vehicles.

USABC has based development and funding decisions on the results of objective hardware evaluations performed in DOE National Laboratories. These tests have been invaluable in determining the true capability and state of development of many advanced batteries. The result is a general agreement on the most promising technologies for the future. Beyond the currently available batteries (lead acid, nickel cadmium, nickel iron), the mid-term batteries will be nickel metal hydride, sodium sulfur and sodium nickel chloride. The long-term batteries will be lithium iron disulfide and lithium polymer. USABC has awarded more than $132 million to six battery developers pursuing these technologies.

Battery Development Process

An understanding of the battery development process helps to characterize the state of development of the technology. Battery development is a scale-up progression from electrochemistry to cells to modules to full-size packs. It's a process of building confidence steadily and progressing to the next step as quickly as success is achieved. This scale-up process is challenging because it requires balancing and optimizing of competing and conflicting goals. Difficult trade-offs must be made to optimize energy, power, cycle life, cost and many other parameters. Trade-offs made to improve one parameter sometimes compromise another parameter and the resulting process is often "two steps forward and one step back".

A full-size battery pack, capable of powering a vehicle, contains hundreds or even thousands of individual battery cells. Full-size packs can be expected to exhibit application problems not apparent at the cell or module level - problems in areas such as thermal management and cell equalization. Consequently, data from a cell or a module cannot necessarily be extrapolated to a full-size pack.

Additionally, the battery development process must be in sync with the vehicle development process. For example, 1998 vehicle programs are now in the early stages of the product development process and battery systems for these vehicles are being selected and integrated into vehicle designs now. Battery systems currently in the scale-up process are not candidates for these vehicle programs due to the uncertainty and high risk of the battery development. Battery systems that have completed scale-up and have met all criteria at the full-size pack level are candidates and can be considered relative to other viable alternatives.

Current Status

So, where are we today? We have made some very encouraging progress. All USABC developers are producing actual batteries that are under test in the national labs. For the mid-term batteries, most work is at the cell or module level and the hardware is demonstrating very good energy relative to currently available batteries. Some full-size packs have been produced, but none have achieved all of the mid-term criteria. To meet all of the mid-term criteria concurrently will require further development, refinement , and possibly fundamental chemistry changes focused at improved cycle life and durability performance.

Perhaps the biggest challenge is that, at this point, it's not clear how the cost goals will be achieved. Early commercialization will be costly and funding support may be necessary to offset capitalization of manufacturing facilities and cost of the resulting batteries in the start-up phase. To achieve true commercial viability, battery costs must be reduced to the level where the process is self-sustaining.

Next Steps

The immediate work to be undertaken now is the materials and process development to achieve the cost and performance criteria. The current USABC estimate is that first packs meeting all mid-term criteria will be achieved in mid-1996. At that point, it will be appropriate to build a number of packs to verify cycle life, safety and quality on a statistical basis. Concurrently, the commercialization process to design and construct a pilot facility could begin. This would be a low volume facility to develop low cost battery manufacturing processes and produce initial volumes. Our initial estimate is that a pilot facility capable of producing 2,000 - 5,000 battery packs per year could be on-line by mid-1999. Design and construction of a high-volume facility would follow. This timing is aggressive and includes significant overlap. It is typical of the timing required to commercialize other vehicle systems incorporating new technology.

Taking a technology through scale-up and into pilot commercialization is costly in terms of both staffing and funding. The USABC is fostering competitive development at this time, but is planning to focus our development portfolio on fewer contracts in the future. For the mid-term technologies, the next 6-12 months will be used to identify the most promising developments warranting enhanced support and discontinuing efforts on those that do not live up to their promise.

A very encouraging development has been the formation of GM Ovonic, a new joint venture formed by private industry to accelerate commercialization of one of the USABC mid-term technologies. This venture would not have been possible without the USABC and the ultimate success of the venture is highly dependent on continued development by USABC to advance the technology to commercial viability.

Additional information on current status and next steps is contained in the USABC report recently prepared for the California Air Resources Board Workshop. The report has been submitted as part of the written record of this hearing. CARB and the USABC have committed to a close working relationship with open communication. CARB has accepted a USABC invitation to join the USABC process as an observer at the monthly meeting of the USABC Technical Committee.

Future Plans

This first phase of the USABC has the goals of commercializing a mid-term technology and demonstrating feasibility of a long-term technology. A successful program will require a sustained commitment by all stakeholders to the original funding of $262 million. Beyond this, the second phase will continue development of the most promising long-term technologies which will enable electric transportation to be competitive with gasoline transportation.

The USABC and the Partnership for New Generation of Vehicles have agreed to integrate their development as much as possible. USABC will use its existing structures and processes to manage the development of electrochemical batteries and capacitors for PNGV. Further opportunities for cooperation and integration are being explored.

In conclusion, I offer the observation that the challenge facing us collectively is one of teamwork as much as technology......teamwork between competing automobile manufacturers, teamwork between vehicle manufacturers and battery manufacturers, teamwork between industry and government. We have already accomplished more together than any of us could have accomplished separately. Further cooperation is the key to our ongoing success.

The USABC looks forward to providing continued leadership toward our mutual goal of developing advanced batteries for commercially-viable electric vehicles.

Thank you.

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Date: February 18, 1994

Subject: January 24, 1994 Wall Street Journal Article

From: John F. Williams - USABC

To: Jack Guy - EPRI

On behalf of myself and the USABC, I am writing to express our shock, disappointment and frustration at the suggestions and comments attributed to you in the subject article. Since you were one of the founding members of the USABC, I find it difficult to comprehend your wondering "whether the consortium might have deliberately set itself an impossible goal". That suggestion is patently untrue. Furthermore, the resulting false and damaging perception complicates the significant technical and business challenges faced by the USABC.

The facts are that you and other EPRI personnel were present and participated fully in the meetings and discussions leading to the establishment of the mid-term and long-term advanced battery criteria. The resulting technical specifications were based on inputs from the auto industry and other consortium members concerning factors such as electric vehicle range and acceleration, battery recharge time and cycle life, and many other requirements which ultimately determine the marketplace viability of the end product for the customer. These specifications have been widely accepted in the battery industry as a good balance between "what's ideal" and "what's possible." The USABC has been proud to award six major contracts to battery developers striving to meet these specifications.

The USABC has other significant accomplishments, including:

- Establishing the framework for cooperation among all the stakeholders, including EPRI, DOE, Chrysler, Ford and General Motors
- Negotiating CRADAs with five (5) National Laboratories to support testing and development of USABC advanced batteries
- Developing and publishing Standard Battery Test Procedures to enable objective evaluation of electric vehicle batteries in independent laboratories
- Developing vehicle integration requirements to scale up cell-level technology into complete on-board subsystems

The USABC has made significant progress and does not share your view that our desire is to "(not) come up with a battery." The consortium is investing a quarter of a billion dollars in the development of advanced batteries. It would be ridiculous to spend that amount of money to demonstrate that the goal is "impossible".

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The USABC does not share your view that an "improvement in the lead-acid batteries...would be good enough." These batteries result in low range vehicles that do not meet our customers' requirements. In November, the U.S. Department of Energy emphasized the importance of an advanced battery, stating:

> "...the single most important technological obstacle facing the auto industry in placing electric vehicles in the California market by 1998 is the lack of a low-cost battery that provides adequate acceleration power and travels a minimum distance of 100 miles before recharging becomes necessary."

Clearly the federal government recognizes that what's needed for commercial viability is a battery with high energy and low cost.

This is, in fact, the premise on which the auto companies, the utilities, and the government have entered into cooperation to develop advanced batteries for EV applications through the USABC. If EPRI or any of its employees have information to the contrary, please make it available to USABC immediately.

It should be self-evident that speculation or assumptions of improper or illegal activity should not be publicized in the national press by USABC participants before taking steps to determine the truth of the allegations. The USABC has in place Public Affairs procedures designed to make it easy for any participant to determine the facts about any question he or she is planning to discuss with the press. Please be informed that failure to follow these procedures carries significant legal risk, as well as the more obvious business, political, and regulatory risks.

My colleagues and I care deeply about air quality, the environment and providing our customers with safe, affordable, clean transportation. We are devoting years of our lives and our careers to make the USABC successful. We would appreciate your constructive support of the consortium.

John F. Williams

John F. Williams
Chairman, USABC

c: Management Committee

THE WALL STREET JOURNAL/Jan. 24, 1994

Californians Collide With Folks in Detroit Over the Electric Car

Big Three Say Technology Is Long Way Off, but State Doesn't Want to Hear It

Harking Back to Air Bags

By OSCAR SURIS
Staff Reporter of THE WALL STREET JOURNAL

LOS ANGELES – Tom Hayden, the longtime liberal activist and now a gray-haired state senator, has found a new vehicle for protest: an electric car. His cause is cleaner air.

Under the creaky hood of his dingy white Ford Escort station wagon are nothing but batteries – 18 of them, weighing several hundred pounds. The converted vehicle is quiet, smog-free, and "perfectly adequate for tooling around the city," says [illegible] Hayden. So auto companies ought to [illegible] up to build electric cars for everybody, he says.

But nearly a continent – and cultural light-years – away, Detroit has a one-word answer: nonsense. Sure, the auto companies could make electric cars, concedes Sam Leonard, director of auto-emission control at General Motors Corp. But, he maintains, nobody would want to buy them. He could lead a chorus of that refrain from one end of the auto industry to the other.

Culture Gap

And therein lie the elements for what may turn into one of the nastiest cultural clashes of the 1990s – between the motor heads of Detroit and the electric-car crowd in California. For what is nonsense in the Motor City looks like the future to an unlikely coalition forming on the West Coast. It consists of environmentalists, venture capitalists, electrochemists, mechanical engineers, the electric-utility industry and politicians desperate for a new jobs-generating industry. They all believe the future should start now.

"It's going to be a big battle," says Dianne Wittenberg, manager of electric transportation at Southern California Edison Co. in Rosemead, which has an obvious interest in selling the power [illegible]at would recharge electric cars.

Emboldening the auto industry's critics is a belief by many that Detroit has blown its credibility concerning its responses to demands for change. Critics recall how auto makers used to claim that consumers would never pay for catalytic converters, or air bags, or wrinkle-proof bumpers. "Fortunately, there are enough people who are old enough to know the auto industry's history of deceit," Mr. Hayden says.

So it is that California's requirement that car makers sell a certain percentage of zero-emission vehicles – most likely electrics – by 1998 is threatening to spread. Clean-air regulators in a dozen states from Maine to Virginia – plus Washington, D.C. – are to begin deciding next month whether to impose California-style rules. If all do, then half the U.S. car market would be covered by a mandate effectively requiring that one in every 10 new cars sold after the year 2002 be electric.

Billions at Stake

Understandably, this has gotten Detroit's attention. The Big Three have billions invested in internal-combustion engines. They are spending billions more to make conventional cars comply with the tougher emissions standards of the 1990 amendments to the Clean Air Act and with similar rules set by California. For instance, California also wants conventional cars to carry computerized devices that tell drivers when their vehicles are spewing out too much noxious stuff.

"We're going to go to market with a system that's going to light up the dashboard like a Christmas tree," cracks John F. Smith Jr., GM's president and chief executive officer. "It's going to make a lot of people mad."

To try to prevent the electric-car movement from establishing itself in the Northeast, the Big Three have been promoting their own clean-air plan, one they maintain would be more palatable to consumers and easier for the car companies to meet. And in California, a bill has been introduced that attacks the state's zero-emission mandate.

What's Possible?

"We're not ready," declares Ford Motor Co. Chairman Alex Trotman. "We are simply unable to provide a vehicle that provides the range that is acceptable to customers out [in California] or anywhere else in the United States at a price that is affordable." Mr. Hayden's converted Escort, industry experts say, would sell for at least $30,000 and would be lucky to go 100 miles between eight-hour charges.

But to electric-car proponents in California, Detroit's marketing concerns aren't the issue. Rather, it is whether electric cars are technologically feasible. The California Air Resources Board will hold a public review of auto technology later this year to help determine that. Back in the 1970s, when CARB found in favor of exhaust-scrubbing catalytic converters for cars – despite industry protests – the technology in fact followed.

So, like conspiracy theorists reviewing grainy old newsreels, some electric-car advocates detect a Detroit plot to kill a promising new technology. Take the U.S. Advanced Battery Consortium, a Big Three-led, $260 million group formed three years ago to search for the Missing Link – a compact, lightweight, long-lasting, quick-charging battery that is capable of making electric cars match gasoline-powered autos.

As commercial-development manager for the Electric Power Research Institute, Jack Guy is also hunting for that elusive battery. His coalition of utilities has put more than $25 million into battery research, including contributions to the battery consortium. But Mr. Guy wonders whether the consortium might have deliberately set itself an impossible goal – a breakthrough battery – in hopes of sabotaging California's electric-vehicle mandate.

"If you don't want [electric cars] to happen quickly," says Mr. Guy, "you don't come up with a battery." Just maybe, he argues, a breakthrough battery isn't necessary right now. Maybe an improvement in the lead-acid batteries in Mr. Hayden's Escort would be good enough.

Wanted: Another Silicon Valley

Mr. Guy's group is investing $6.6 million in an Austin, Texas, company that is to start manufacturing such batteries for cars this year. The company, Electrosource Inc., maintains its battery pack will sell for less than $10,000. That is much less than the $45,000 that Ford says is the cost of the sodium-sulfur battery pack used in its prototype electric cars. The people behind the battery consortium say they know the limitations of lead-acid batteries, and therefore are concentrating on finding better types.

This sort of stance by the auto industry is what irritates utility-industry executives, battery developers and Wall Street investors. Many West Coast political and

THE WALL STREET JOURNAL/Jan. 24, 1994

ELECTRIC VEHICLES

LIFORNIANS COLLIDE (Continued)

business leaders ask why the Big Three can't see the immediate potential to create a Silicon Valley for the American electric-car industry (preferably not too far from the real Silicon Valley). Aren't they worried about losing another lucrative market to the Japanese or the Europeans (though they haven't leapt into the technology in a big way, either)?

Electric-car believers see a niche market of environmentally friendly folks who want a second or third car to drive for commutes of 40 miles or less. Take actor Leslie Nielsen, star of "Airplane" and "The Naked Gun." When he isn't driving one of his three gas-guzzling Bentleys, he is usually tooling around the hills of West Hollywood in an electric-powered Toyota Paseo.

"It's just a lovely little black bug that zips around the traffic," says Mr. Nielsen, who modeled for an electric-car ad in the Neiman Marcus Christmas catalog. "It's a great second car."

The Potential Buyers

Or maybe even a first car, according to Southern California Edison. In a survey the utility commissioned last year of 1,000 Californians – 70% of whom were aware of electric cars' limited range – more than 60% expressed an interest in buying an electric car if it were as affordable as regular cars.

That suggests it wouldn't be hard to find enough buyers to meet the state requirement that 2% of the cars a company sells in California be zero-emission by 1998. Two percent of California's two million-vehicle-a-year market is 40,000. To put that into perspective, some European auto makers struggle to sell 20,000 cars a year in the whole U.S. market. (There are about 3,000 electric cars on the road currently.)

Clearly, the leaders of this movement fervently believe in the electric dream. At an electric-vehicle conference last fall in Phoenix, Bill Stephenson, an executive for Arizona Public Service Co., led an emotional defense of the cause. "So call us unreasonable," Mr. Stephenson said in challenging the Big Three's criticism of California's zero-emission mandate. "But what we believe are unreasonable and unacceptable are delay tactics."

Regardless of whether the California mandate sticks and spreads, a few who are at the forefront of electric-vehicle development aim to plow ahead. U.S. Electricar, a small company located in the lush valleys of quaint Sebastopol, Calif., converts Geo Prizms and Chevy S-10 pickup trucks to electric power to sell to federal researchers, electric utilities and the few individual buyers like Mr. Nielsen.

Though Electricar has sold just 200 vehicles since 1983, it expects to sell 1,150 this year. If it does, it will have done so with indirect help from GM. When GM spiked plans to build the electric Impact for next year, fleet managers found themselves in a jam to meet federal requirements to begin adding alternative-fuel vehicles – creating an opportunity for Electricar. Moreover, the Power Control Systems division of GM's Hughes Aircraft Corp. unit in Torrance, Calif., makes the drive system for Electricar's vehicles.

Take a Ride

Electricar converts vehicles by removing their internal-combustion engines and replacing them with shiny, briefcase-sized boxes from Hughes. Crammed with electronics, these boxes become the engines that drive Electricar's $40,000 vehicles, with the batteries placed under the car. If the vehicles were mass-produced Detroit-style, their cost could be cut in half, Electricar says.

That, electric-car advocates argue, is the flaw in the industry's argument that electric cars wouldn't be affordable. Cruder conversions already sell for much less than $40,000. And as for whether people will like driving them, well, just take a ride with Daniel D. Rivers, the manager of Hughes's electric-vehicle program.

With a head-snapping screech out of his parking lot, Dr. Rivers punches the peddle on an Electricar Geo Prizm. Laughing as he barrels around a corner, he brags about the drive system's torque curve, claiming the car can zoom to 90 miles an hour in first gear.

"We're trying to see who can get the first legitimate traffic ticket in one," says Dr. Rivers. "I think the consumer will like it."

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A SUMMARY OF THE STATUS OF ADVANCED BATTERIES FOR USE IN ZERO-EMISSION VEHICLES

25 MARCH 1994

Prepared by the United States Advanced Battery Consortium for presentation at the California Air Resources Board Workshop on Low-Emission Vehicles and Zero-Emission Vehicles

Chrysler • Ford • General Motors

A SUMMARY OF THE STATUS OF ADVANCED BATTERIES FOR USE IN ZERO-EMISSION VEHICLES

INTRODUCTION

In response to the draft technical document -- Zero-Emission Vehicle Update -- prepared by the Mobile Source Division of the California Air Resources Board (ARB), the United States Advanced Battery Consortium is pleased to submit this summary of the status of advanced battery technologies that are under consideration for use in Zero-Emission Vehicles (ZEVs). Following a brief review of the market requirements for such batteries, the main sections of this summary document will, from the USABC perspective, address: (i) the development status and perceived timing for commercialization of several candidate battery technologies; (ii) the commercialization process envisioned for electric vehicle (EV) batteries; and (iii) the role of the USABC in the development and commercialization activities.

The market requirements for EV batteries are driven by the following considerations. First, unless ZEVs can be successfully marketed to the general public, they will not have the desired impact on air quality. ZEV "patrons", industrial fleet applications, and government-agency vehicles do not, by themselves, provide sufficient market quantities. Patrons of electric vehicles are enthusiastic, are willing and can afford to pay a premium for the vehicle, and may be willing to put up with some shortcomings of a revolutionary vehicle. But, they are few in number -- perhaps only a few thousand. Specialized, dedicated applications -- light cargo and utility vehicles -- are well suited for electric vehicles because of their short-trip, urban nature. But the number of special application vehicles is far less than 1 percent of the total vehicle market. This means that unless electric vehicles can be sold extensively to the general public, the numbers of vehicles in use in urban areas will not be sufficient to meet the air quality goals.

Market research has shown that the public would consider purchase of an electric vehicle -- _if_ it meets their needs for range, payload, performance, and comfort with an initial price and ongoing operating costs that family budgets can sustain. Range, in terms of a rated value on the Federal Urban Driving Schedule, must be at least 125 miles -- 50 miles for an average daily usage, 50 miles for reserve, and 25 miles for the equivalent climate control system load. Customers appear to be unwilling to pay much over $1000 more than the equivalent internal combustion engine (ICE) vehicle. For this they expect a vehicle with essentially no maintenance and very high reliability.

The battery technology is clearly the limiting element in developing EVs that will satisfy these customer needs. It must be packaged into a space compatible with structural requirements, passenger ergonomics, vehicle aerodynamics, and safety constraints. Its energy content must be sufficient to provide at least 100 miles of range under realistic driving conditions – heavy stop-and-go traffic, hilly terrain, and adverse climates. It must provide enough power at any state-of-charge to be safely driveable in traffic dominated by existing ICE vehicles. It must be very reliable and maintenance free – in keeping with a major perceived advantage of electric vehicles. It must meet all these criteria, and be affordable as well.

Battery cost is, of all the technological hurdles, the most critical and difficult to overcome. The initial cost of the battery, even in high-volume production, is likely to be in excess of any premium the public is willing to pay for the perceived benefits of an electric vehicle. This means that the battery cost must be amortizable over its useful life, with a lessor to finance the initial cost for the consumer/lessee. This, in turn, requires that the battery manufacturer provide an adequate warranty for the life of the battery. Since warranty cost is included in the battery selling price, the technology must provide an affordable combination of low manufacturing cost and long life in service. Incentives may be used by governments to compensate for higher startup costs, but to have a sustainable technology customers must have a monthly cash outlay that is no more than their savings in fuel and maintenance costs for a conventional vehicle. Otherwise, there will be no market pull to make EVs economically sensible.

To be successful, a new technology must create a market pull based on what customers want, and are willing to buy in preference to competing technologies. By itself, no mandate can push the public into acceptance of a technology that doesn't meet their needs.

STATUS OF CANDIDATE BATTERY TECHNOLOGIES

Although a few candidates are emerging as the most promising, there is still no single clear choice among the many EV battery technologies developed over the years by DOE and industry. The technologies are at various levels of maturity, in many different forms, and with numerous developers involved. The USABC was formed to focus the development efforts and accelerate the most promising technologies to market as soon as possible.

The challenge facing the USABC was selection of technologies to support in their further development. The first step was to set goals for the candidate technologies in two timeframes – midterm and longterm. Midterm goals were set to provide a compromise between performance, cost, and availability within the earliest possible timing. Nonetheless, these goals are responsive to the minimum requirements of the marketplace. Longterm goals were set to provide EV performance and economics that would be competitive with internal-combustion engine (ICE) vehicles. So-called "nearterm" goals were not established because of the relative maturity of such candidates (e.g., lead-acid, nickel-iron, nickel-cadmium), and because of the relatively small gains that could be realized from any further development efforts.

There are no promising batteries expected to be in production by 1998. Batteries in production today fall far short of minimum performance and life goals. Commitments to produce in the future are not viable until key readiness criteria have been verified. Although a number of battery technologies are projected to meet most of the USABC midterm goals, their cost, calendar life, cycle life, and overall performance have yet to be demonstrated. Further, their manufacturing process capabilities also must be verified to ensure that high-quality, low-cost batteries can be produced in high volume with acceptable warranties. Establishment of full-volume (≥ 10,000 batteries/year) production facilities will take four to five years after the initial commitment to produce is made.

The five technologies identified in the California ARB technical document as extremely promising have already been considered by the USABC. Their status is reassessed on a continuing basis, and the most recent evaluations are summarized below.

Sodium-nickel chloride. The major developer of sodium-nickel chloride batteries is AEG, a subsidiary of Daimler-Benz AG in Germany. After several iterations in cell design, AEG has established a small, prototype pilot line for manufacture of their SL9 cell. Batteries using this technology are now under test in vehicles and laboratories in Europe and the US. The USABC is conducting tests on one battery at the Idaho National Engineering Lab. Performance data from these tests show a severe decay in available power as the battery is discharged. At 20% state-of-charge (i.e., 80% depth-of-discharge) the power is only one-half of that available at the initial, fully charged condition. This is unacceptable for EV's.

AEG is pursuing improvements in both cell and battery systems technology. The cell effort is aimed at increasing power at low state-of-charge conditions. The battery systems effort is addressing thermal enclosure design, cooling systems for higher sustained power, simplified controls, and low-cost battery assembly methods. Even with these efforts, it is not clear that AEG will be successful in achieving the USABC Midterm power and cost goals.

The steps necessary to reach a positive commercialization decision include qualification of an improved cell, final specification of all manufacturing processes, and implementation of the improved cell and battery designs in the existing small pilot line facilities. Approximately 50 batteries would undergo intensive testing to verify the readiness of the technology for commercialization. Such testing would require at least 6 to 12 months to complete.Thus, even if successful, the timing of the AEG development efforts is such that a decision to build a pilot plant for initial commercial production could not be made before mid-1997.

Nickel-metal hydride. The major developers of nickel-metal hydride batteries under contract to the USABC are Ovonic Battery Company and SAFT America. Cell, module, and pack hardware are being tested in laboratories and in vehicles. While each contract is at a different stage of development, it can be stated that neither company is presently fully meeting the USABC midterm criteria.

Ovonic Battery Company (OBC) received the first USABC contract to develop NiMH batteries. Ovonic is in the second phase of a three phase program and is progressing very well as they move through their program. Performance has been improving consistently and all deliverables have been met on or ahead of schedule. Preliminary test results at Argonne National Laboratory (ANL) have shown that this technology holds promise of meeting USABC midterm performance criteria. Phase 2 modules are now under test at ANL, including life and temperature testing to determine thermal management requirements. While these modules continue to cycle on the rigorous USABC Dynamic Stress Test (DST), the midterm criterion for cycle life (600 cycles) has not yet been reached. The criteria for success are to maintain both energy and peak pulse power above 80% of their initial ratings (30-second pulse at 2/3 open circuit voltage and 80% depth-of-discharge). Based on OBC's technical progress, USABC agreed to install full-size Phase 2 packs in vehicles prior to completion of Phase 3. These are now being delivered and integrated into vehicles.

Projections of battery selling price made by Ovonic, and independently by USABC, are currently in excess of the USABC midterm goal of $150/kWh. OBC has proposed to the USABC additional development aimed at reducing materials and manufacturing costs to meet this goal. Overall, it will take more than two additional years before final verification testing can be started for this improved technology. Subsequent verification of cycle life will take about one additional year. This could result in eventual achievement of our price goal, with specific energy levels well above the midterm criteria.

In parallel with the USABC program, General Motors recently announced an agreement with OBC to further develop, manufacture and commercialize Ovonic NiMH batteries for EVs. The impact this agreement will have on the timing for volume production is unknown.

SAFT is also making excellent progress in their nickel-metal hydride development program. The program is structured on a number of hardware deliverables to measure progress against defined performance goals. Although the initial and interim goals are below USABC targets, they plan to meet the USABC midterm goals in the final deliverables. The first SAFT 12-volt modules were delivered to the Sandia National Laboratory in July 1993. Performance and cycling tests are in progress using the USABC Dynamic Stress Test (DST) profile. SAFT has achieved well in excess of the midterm 600 cycles on similar cells at a one-hour constant-current rate to 80% depth of discharge. The second hardware deliverables were provided on schedule in January 1994. By the end of 1994, four 40-kWh battery packs will have been delivered. These packs are expected to meet at least some of the USABC goals. The final contract deliverables are scheduled for the end of 1995 and the first quarter of 1996. Testing of these full-sized packs in the laboratory and in vehicles will require up to 12 additional months to verify achievement of the cycle life goal.

Throughout the development, efforts will continue towards achieving the USABC battery price goal. Even if successful, a decision to commercialize this technology could not be made before mid-1997. Thereafter, production facilities would have to be set up and commissioned before significant production rates could be achieved.

Sodium-sulfur. Two developers -- ABB in Germany and Silent Power in England -- are pursuing sodium-sulfur technology -- each with unique approaches to meeting the midterm goals. ABB is the supplier of prototype sodium-sulfur batteries to Ford for their Ecostar demonstration fleet of 105 vehicles, but is not a USABC contractor. The planned 30-month evaluation by Ford will identify integration issues, establish service life, and focus future development. A next-generation battery design would provide improvements in thermal management, vehicle interfaces, battery reliability and life, and reduced manufacturing cost. Prototypes of this new design could be available by early 1995. However, a decision to commercialize has not been made for the ABB technology; this will need to be based on results from the fleet testing and hardware evaluation of the improved battery design.

Silent Power is currently pursuing major improvements in their cell and battery systems technology. Cell development is being funded internally, while the battery systems development is being co-funded by USABC and Silent Power. Principal development goals are higher cell power, longer life, and reduced manufacturing costs. Although Silent Power has established a small, prototype pilot line for their present technology, it will need approximately two years to incorporate the improved technology. Another year of field trials would then be needed to verify the readiness of this technology for commercialization. The earliest a commercialization decision could be reached is thus the beginning of 1997. Once a commitment to production is made, it will then take at least two more years to build, commission, and rampup the first manufacturing plant.

Advanced Lead-Acid. Lead-acid batteries have been used throughout the world for many years as traction batteries using technologies similar to those found in ordinary automotive accessory batteries. This traditional lead-acid technology in its present form cannot meet future EV needs for either commercial or private use. They are limited by low energy density, short cycle life, the need for frequent maintenance, and, in flooded designs, the possibility of hydrogen off-gassing which poses a safety hazard.

Some advanced lead-acid batteries are under development with characteristics superior to the traditional flooded technologies. Valve-regulated lead-acid (VRLA) technology recombines gasses to yield a product with improved specific energy and power capabilities. The International Lead Zinc Research Organization, Inc.(ILZRO), has funded programs to accelerate the development of this technology.

Two other advanced development projects are the sealed bipolar and quasi-bipolar lead-acid battery systems. True bipolar systems have in the past suffered from electrolyte leakage at the seals and pinhole corrosion of the bipolar interface. These problems lead to performance degradation and premature failure. The quasi-bipolar design utilizes a unique grid design, paste formulation, and curing process. Only small 30 to 40 Ah, 4-volt cells have been built and tested. Larger 100-Ah, 12-volt modules are needed to properly evaluate this technology.

Published performance projections for these advanced systems range from about 40 to 55 Wh/kg and 200 to 300 W/kg. Life-times range from 200 to 1000 cycles. Much of this data is on small laboratory cells, cycled under constant current conditions which do not stress the battery as one would encounter in EV applications. Previous testing of lead-acid batteries show a reduction in life of about a factor of two in comparing constant-current cycling with Dynamic Stress Test cycling. To date, none of the cycle life projections have been demonstrated in independent tests using USABC test procedures. Full-sized battery modules, assembled on a prototype pilot line, are needed to reliably evaluate these technologies.

Even if successful, the relatively low specific energy of lead-acid technologies imply that they will be supplanted by a superior midterm technology. It is highly probable that this will occur prior to the end of this decade. This makes the investment in a high-volume production plant seriously questionable for lead-acid. The amortization of capital equipment would have to be accelerated to reduce the risk of premature obsolescence; the resulting capital expense will potentially make the battery costs unacceptable.

Lithium-metal sulfide. Lithium Metal Sulfide battery technology, originally developed by the Argonne National Laboratory (ANL), was one of the first technologies evaluated by the USABC and was subsequently selected as a longterm battery candidate. The maturity of the technology at that time did not warrant its selection as a midterm candidate, but it offered, in the advanced bipolar form, the potential of meeting the longterm goals. As a result, the USABC is currently developing an advanced bipolar $LiAl/FeS_2$ battery in conjunction with the team of SAFT America and ANL. SAFT has been using this technology for some time to manufacture military batteries, for use as a non-rechargeable power source. Their high-volume manufacturing experience and related facilities will enhance the probability of bringing this EV battery technology to market after feasibility has been demonstrated.

The monopolar form of this battery was bypassed by the USABC in favor of the bipolar form primarily due to performance and cost. As a low voltage battery, the monopolar configuration is perhaps a good choice for less demanding consumer market applications, such as an electric lawnmower. In a high voltage system, however, the additional material packaging inefficiencies, and higher assembly costs to interconnect the individual monopolar cells precluded this approach from further consideration.

The USABC team of SAFT and ANL must resolve many technical issues of high-temperature materials compatibilities, seals, separators, within aggressive cost goals. This is why that program is considered a longterm development.

The USABC has not verified the status of other lithium-metal sulfide battery developments, but would consider doing so when relevant developer-provided test data and hardware samples are made available. Of particular interest would be any results showing good calendar and cycle life in multi-cell modules under dynamic load conditions such as the Dynamic Stress Test profile. Low cost and the ability to scale up to the desired EV voltages are also required.

For all of the above technologies, bringing a battery into initial commercial production (at least 2,000 units/year) requires three principal steps -- verification of design and process readiness, manufacturing plant construction and commissioning, and final validation of the plant product. Verification of readiness includes sufficient testing with positive results to decide to build a pilot production plant. Such a plant will provide verification of the manufacturing processes to be used in a full-volume plant. As noted above, the time required to reach this initial commercialization decision varies among the several promising technologies. From that point, construction and commissioning of the pilot manufacturing plant will generally require at least two years to complete. This is based on developers' experience from setup of small, prototype pilot line facilities. In most cases new processing equipment must be developed to achieve economies of scale that will reduce production costs. Battery production proveout/validation will take several months of intensive testing at the vehicle level. Safety, durability, and robustness in adverse environments must be demonstrated using initial product from the manufacturing facilities. In total, at least three years is needed from the decision to build an initial pilot production plant to the release of battery product for sale to customers. Thereafter, scaleup of production to achieve the high-volume cost goals will generally take another two years.

EV BATTERY COMMERCIALIZATION PROCESS

Commercialization of a promising battery technology requires sufficient time to reduce the investment risk to an acceptable level. A completely new industry must be created to accomplish our goals. The USABC has undertaken the task of developing a commercialization plan which may be used when a candidate technology has demonstrated its technical feasibility. During this investigation, the commercialization group has come to the following conclusions.

Commercialization of any EV battery program requires scale-up of production volumes in an incremental fashion, allowing the processes to be developed, verified, productionized and validated in a controlled, orderly fashion. This involves the following steps:

i) At least 30 experimental battery packs for technology development and verification in laboratory and in-vehicle testing.

ii) About 100 packs for vehicle fleet safety, quality assurance, and product design validation.

iii) Construction and commissioning of a pilot production plant to validate manufacturing processes and product designs. (Minimum rate of 2000 packs per year.)

iv) Construction and commissioning of a full-volume manufacturing plant (Production rate of at least 10,000 packs per year)

A decision to build a battery manufacturing plant (with sufficient capacity to meet the mandated volumes) must be based on firm advanced orders from the vehicle manufacturers. Due to the expected high unit costs associated with the midterm battery technologies, it is expected that a significant subsidy will be required to mitigate the anticipated losses during the low-volume validation periods. It is necessary to accurately understand the actual battery costs at each level of production together with the expected level and duration of any subsidies that might be available before a commercialization business case can be put together. This is extremely difficult to do, since there are several competing technologies and volumes of each technology would be difficult to project. Once a detailed business plan is complete, orders could be solicited from the vehicle manufacturers.

Firm orders from the vehicle manufacturers are contingent on selling price guarantees and acceptable battery warranty. This sounds straightforward, but in order to establish a credible warranty it is necessary to have established, with high statistical confidence, the durability and reliability of each battery technology being considered. This is far from complete at this time. The risk of warranting a $10,000 battery (e.g., a 40 kWh battery at $250/kWh) is extremely high without sufficient cycle life and calendar life data.

Selling prices must reflect the use of proven, high-quality manufacturing processes, not all of which have been specified completely. A key part of the development activity is to evaluate and optimize the processes for low-cost production of EV batteries. At this time, many processes still need to be developed so that the USABC cost targets can be met. These efforts must include lower level component and raw materials suppliers, especially for intrinsically high-cost materials.

Battery warranty must be based on life verification testing, which can be accelerated only to a limited extent. As mentioned earlier, this is essential to commitments for advanced orders from the vehicle manufacturers. Accelerated test methods include both time compression at actual-use stress levels, and increased stress levels to shorten the time-to-failure for a given failure mode. Time compression could be used to verify cycle life in a much shorter time than in actual use (e.g., a 600-cycle test could be completed in about one year, instead of the 2-5 years that would correspond to actual-use conditions). On the other hand, there are no commonly accepted methods of accelerating calendar life testing, with proven correlation to actual customer use. This is due to the complex nature of the critical battery failure modes that must be preserved in the test regimes; excessive stress levels can easily introduce new, irrelevant failure modes. Accelerated testing and correlation studies have been developed for many products, but this is a new field of endeavor for EV batteries.

In summary, the total time to commercialize a battery from successful research and development, based on the steps outlined above, would take approximately 4 to 5 years from the date a candidate has proven it is capable of meeting the basic traction battery requirements. At best, assuming a candidate technology demonstrates its capability to meet USABC midterm requirements at the end of 1996, full-volume production could not be reasonably expected to be in place prior to the year 2000.

USABC STRATEGY

The United States Advanced Battery Consortium (USABC) was formed to select the most promising battery technologies, and to work with battery developers and other companies to conduct research and development of the selected advanced battery technologies. To sufficiently research and develop the many alternatives to the point of selecting a viable technology in time to meet legislated requirements is beyond the resource capabilities of any individual manufacturer or technical group. As a consortium, a great deal more can be accomplished and faster than any one organization could do alone. It allows leveraging resources, both technical and financial, by jointly conducting the high risk, high cost research and development associated with advanced battery systems. A recent status report provided to the U. S. Senate is attached as Appendix A.

The USABC strategy is to accelerate the development and prove out the most promising technologies as needed to support and realize their commercialization as soon as possible. This effort is needed to provide in a timely manner advance batteries which will increase range, improve performance, and reduce the cost of electric vehicles.

Major accomplishments of the USABC include:

> i) Establishing a framework for precompetitive cooperation among all stakeholders -- EPRI, DOE, Chrysler, Ford, and General Motors.

In 1991, the framework for precompetitive cooperation between Chrysler, Ford, General Motors, Electric Power Research Institute (EPRI) and the Department of Energy (DOE) was developed. It was completed with the signing of a Cooperative Agreement between the USABC and DOE on September 25, 1991. The consortium subsequently awarded on a competitive basis a variety of contracts with battery developers and set up several CRADAs with DOE Laboratories to assist in the development and prove out of the selected advance battery technologies.

The USABC organization is headed by the Partners Committee, which handles policy matters and oversees the Management Committee, who in turn has responsibility for the overall operation of the business. The key Management Committee officer positions of Chairman, Secretary, Treasurer and External Affairs rotate on a yearly basis between the USABC Partners.

The Technical Advisory Committee (TAC), under the direction of the Management Committee, provide the technical expertise to select battery technologies and direct the related USABC technical program research and development activities. The TAC was staffed by experienced personnel from each auto company, EPRI and participating utilities, DOE and DOE National Laboratories. From these resources, individual Battery Technology Work Groups were formed and assigned to direct specific battery technology development programs.

ii) Setting realistic, market-driven goals for Midterm and Longterm battery technologies.

From the beginning, the consortium recognized that there was no clear choice among the many battery technologies developed for electric vehicles over many years by DOE and industry. The candidate technologies were at different levels of development, they were offered in different forms, and, in some cases, they were being developed by a multitude of suppliers. What was needed is a more focused effort towards bringing the most promising technologies for electric vehicles to market.

The challenge facing the USABC was how to select the most promising technologies for development. This challenge was met by developing a set of realistic, market-driven goals, now known as the USABC midterm and longterm criteria. The objectives of this criteria were:

Midterm:	Moderate goals oriented towards technologies capable of meeting the earliest possible timing.
Longterm:	More aggressive goals oriented towards more advanced technologies capable of significantly improving EV performance.

These criteria provided a balanced set of requirements which can be used as a bench mark to evaluate the overall capabilities of the various EV battery technologies under consideration. With this criteria, the USABC can sort through various battery technologies and select those most likely to succeed in meeting the USABC goals. Each set of criteria includes primary and secondary requirements, with most emphasis placed on primary requirements when evaluating battery technologies. Each technology is considered on its own merits and potential for achieving the stated goals. Deficiencies or non-compliance with one or more parameters do not necessarily disqualify an otherwise practical and marketable battery technology.

iii) Negotiating six major contracts to battery developers striving to meet the USABC goals, and engaging the substantial technical resources of five National Laboratories to support development and testing of advanced batteries.

Several advance battery technologies have been identified by the USABC as potential candidates for further development and possible commercialization. They include:

Midterm Technologies:	Nickel Metal Hydride Sodium Sulfur Sodium Nickel Chloride
Longterm Technologies:	Lithium Metal Sulfide Lithium Polymer

After narrowing the field of potential candidates to the above technologies, the USABC Technical Advisory Committee concentrated on establishing development contracts and related DOE National Laboratories CRADAs to support the development programs. The first development program was signed with Ovonic Battery Company of Troy, Michigan during May, 1992. The first CRADAs were signed with Lawrence Berkeley Laboratory and the National Renewable Energy Laboratory during June, 1992. Today, after intensive negotiations, the USABC is actively working on six (6) development contracts and seven (7) CRADAs to support the related technologies. The status of the USABC midterm programs was summarized previously; the longterm programs, which represent a total of over $70 million, are as yet unable to project achievement of all the USABC's longterm goals. Other technologies and/or new suppliers are being considered on a continuous basis by the TAC as they develop. Some of these may result in additional development contracts in the future.

iv) Developing and publishing of Standard Battery Test Procedures to enable objective evaluation of EV batteries in independent labs.

The other half of specifying battery performance criteria is to define how a battery should be tested to verify compliance with the criteria. The "Electric Vehicle Battery Test Procedure Manual" was developed and published by the USABC for that purpose. The initial release was made February, 1993. An updated version will be published in the near future.

The purpose of the manual is threefold:

Outline a standard set of tests for USABC battery systems
Provide a detailed test plan outline for USABC Program Managers
Define related reporting and data acquisition requirements

The manual includes an "Outline of USABC Test Plan for Electric Vehicle Batteries" which is a list of tests to be considered for each battery under evaluation.

v) Developing vehicle integration requirements to scale up cell-level technology into complete on-board battery subsystems.

Some battery developers need manufacturing and quality assurance support from USABC to identify processes that are compatible with high-volume production, and are consistent with today's automotive standards. All developers must conduct Failure Modes and Effects Analyses (FMEAs) at the system level, the product design level, and for the manufacturing processes. The significant (quality-related) and critical (safety-related) characteristics must be identified and a Control Plan generated to assure that these are kept within acceptable tolerances in the final product. With the exception of qualified automotive accessory battery suppliers, EV battery developers need assistance in conducting such analyses. Manufacturing and Supplier Quality Assurance personnel from the USABC Partners are available to support the developers' efforts.

Speaking to the future, the USABC intends to "stay the course" to facilitate commercialization of at least one midterm technology, and to bring one or more longterm technologies to the point of technical feasibility.

A complete product validation test program for a major automotive component like the traction battery involves the following categories of design and production proveout:

> Safety and abuse qualification. Destructive tests involving crash simulations, electrical and thermal controls malfunction, mishandling during shipping and vehicle installation, water immersion, and rough-road shock and vibration.
>
> Durability verification. In-vehicle tests under controlled track environments, including sustained high-speed driving, mileage accumulation profiles, all-weather driving, and rapid recharging if appropriate.
>
> Special tests. Electromagnetic compatibility/interference, freeze-thaw reliability, and accelerated calendar life procedures, as appropriate.

At least 30 batteries are needed for initial verification, with the total approaching 100-150 batteries by the completion of product validation testing. This will provide only the minimum level of statistical confidence in the results.

Verification of a battery technology's readiness for commercialization is expensive; a substantial number of full-size batteries must be tested in robust vehicle environments to develop the necessary confidence in the investment decision. Proveout of battery life cannot easily be accelerated. Test, analysis, and "fix" iterations are required; as battery life is extended, these take increasing periods of time to complete.

Resource limitations will force the USABC to focus on fewer technologies in the future, not more. The high cost of testing, particularly in-vehicle tests, implies that only the most promising technology may be brought to the point of commercialization. The USABC is fostering competitive development at this time, but there is expected to be a winnowing out of the less productive efforts as time progresses. At the same time, emphasis on the longterm technologies must be preserved to assure that EVs will one day be fully competitive with ICE vehicles.

USABC
UNITED
STATES
ADVANCED
BATTERY
CONSORTIUM

Written Testimony of the U.S. Advanced Battery Consortium
Submitted to the
Subcommittee on Interior and Related Agencies
Committee on Appropriations
U.S. House of Representatives

This statement is presented on behalf of the United States Advanced Battery Consortium (USABC), an industry-government partnership formed in 1991 to develop advanced batteries, with the goal of providing increased range and improved performance, at an affordable cost, for electric vehicles in the latter part of this decade (1990s). In 1992, and again in 1993, the USABC reported its progress to this Committee. While advanced battery development is very challenging and high risk, the results to date have been encouraging.

The support of the U.S. Department of Energy (DOE) has been, and is, key to achieving our goals. Not only has DOE been directly involved with the work of USABC, they continue to support much needed, longer range battery research that could result in technologies important to the future work of the USABC. As reported last year, a great deal of ground-breaking and pioneering went into the formation of USABC, but today the promised synergy of the industry-government partnership is being realized.

The specific objective of this statement is to provide an update on the accomplishments of the USABC in 1993 and to confirm our plans for 1994.

1993 ACHIEVEMENTS

One of the first actions of 1993 was to carefully re-examine and refine the purpose of the USABC. This purpose is:

> TO DEVELOP FOR COMMERCIALIZATION ADVANCED BATTERY SYSTEMS THAT WILL PROVIDE INCREASED RANGE AND IMPROVED PERFORMANCE FOR ELECTRIC VEHICLES IN THE LATTER PART OF THE 1990s.

The USABC continues to focus on any and all advanced battery technologies that can achieve this purpose; i.e., technologies with both technical and commercial feasibility. The strategy to accomplish the purpose of USABC has been threefold: teamwork, tools and technologies.

Teamwork

At the level of the Technical Advisory Committee, the membership of the teams, and their roles and responsibilities, were clarified and strengthened for each development contract, CRADA, and initiative. A Working Action Item List is maintained and prioritized, which focuses the team's efforts on the most critical issues. The USABC partners, the Electric Power Research Institute (EPRI), the participating utilities, and the DOE all agreed to increase their support for the Technical Advisory Committee tasks.

A Strategic Planning session was conducted to assure relevance and adequacy of current direction. The portfolio of development contracts was examined, assessed and refined. It was determined that the DOE National Laboratories were providing good fundamental scientific work, which is starting to mature in support of commercialization.

While the work of USABC is focused on batteries, vehicle integration was identified as a key area of emphasis. The partners are cooperating on many aspects of the battery system, such as voltage, power-to-energy ratio, and battery/vehicle partioning requirements.

A Mid-Term Readiness Assessment was completed. A summary statement of data accumulated, as well as future projections, was prepared by the Technical Advisory Committee for consideration by the partner's vehicle programs. While good progress is being made, the conclusion reached based on this Assessment was that an advanced battery would not be ready for the production required to meet the 1998 California sales mandate.

One additional team, the Commercialization Task Force, was formed within USABC in 1993 in support of the refined purpose stated above. Although some of the technologies under development are achieving significantly higher energy than current batteries, all are still extremely high cost and will require extensive manufacturing/process development to achieve the USABC criteria for ultimate price. To address the issue of commercial feasibility, the USABC projects include in-depth cost models when their development has progressed sufficiently to warrant this. To date, these analyses tell us that much remains to be done.

The primary teams of the USABC and their "deliverables" are:

Team	Deliverable
Partners Committee (USCAR)	All Consortia
Management Committee	Strategic Direction
Technical Advisory Committee	Program Support
Program Manager	Operational Direction
Battery Developer	Work
Commercialization Task Force	Production Feasibility/Cost

Tools

The basic tool of the USABC has been the Systems Approach with clear definition of the requirements for vehicle applications. A focus on process improvement has been established. The Process by which Work Gets Done, as well as the roles and responsibilities of each step, has been explicitly stated. A generic Technology Development Process is used on a regular basis, especially in the readiness assessment. A template format was developed for the Program Review Process.

An interim Battery Test Procedure for laboratory testing of advanced batteries was developed and published in order to ensure consistent data and relevant comparisons of all technologies. Benchmark testing of currently available technologies was initiated in order to properly characterize mid-term and long-term advanced technologies.

Each major development contract and CRADA is reviewed quarterly at the monthly Management Committee meetings.

Technology

The USABC announced three additional battery development contracts in 1993. These contracts are: Silent Power for the development of a sodium sulfur battery (a mid-term technology); W. R. Grace for the development of a lithium polymer battery (a long-term technology); and 3M for development of a lithium polymer battery. Both W. R. Grace and 3M have subcontract partners as well. Grace is working with Johnson Controls, Inc., EIC Laboratories, Inc., and Stanford Research Institute, while 3M has a joint effort with Hydro Quebec and Argonne National Laboratory.

Three of the development contracts that were in place in January of 1993 have resulted in working battery hardware that is under evaluation in the DOE National Laboratories (six Cooperative Research and Development Agreements, or CRADAs, define the work requirements in support of USABC at the DOE National Labs).

All of the developers met their milestone deliverables on time and within budget. Some mid-term technologies have been successfully scaled up to full-size packs for vehicle development and evaluation. The long-term lithium technologies presently exist only at the small cell level and their development is focused on building the fundamental electrochemistry in laboratory experiments.

The USABC agreed to purchase five nickel metal hydride battery packs for evaluation from Ovonic Battery Company. These battery packs, however, will not have the performance level of the USABC targets; they will be built at currently achieveable levels, which fall somewhat below the mid-term goals. These will be delivered in 1994.

Several additional technologies and developers were recommended to USABC and several unsolicited proposals were received. The Technology Assessment Process was used to evaluate a broad spectra of electrochemical concepts. Regrettably, most of the proposals were disappointing. The hardware samples submitted did not live up to the claimed performance levels under objective test evaluation in the National Labs. Nevertheless, the USABC stands ready to receive any reasonable proposal, and will undertake hardware assessment of any technology brought forward with the potential for meeting the goals of the USABC.

1994 PLANS

With six substantial development contracts well underway, one of the major tasks of the USABC this year will be to begin the selection process that identifies the technologies warranting enhanced support and development, and discontinuing efforts on those that do not live up to their promise. The Commercialization Task Force formed in 1993 will be an important element in this process.

The next step beyond prove-out of the basic technology is Process Development, which would then hopefully lead to establishment of a Pilot Production facility. While one of the inherent tasks in every development program is to meet the cost goals set forth for the advanced battery, none of the technologies presently meet these goals, or even come close to meeting these goals. Furthermore, it will not be possible to validate future costs until the pilot production process is established. Therefore, plans for 1994 include initiation of the process that leads to this necessary step.

Funding

The $27 million identified in the DOE budget for USABC support in FY95 is well below the level needed to accomplish the remaining tasks of the six development contracts and six CRADAs in place. Because of the slow start-up of the development work at the outset of the formation of USABC, however, which was discussed in last year's testimony, it is believed there will be adequate carry-over funding from FY94 to fulfill the work planned for this next year. It should be noted, however, that additional funding probably will be required in FY96 in order to complete the work presently underway. Again because the start-up of the actual technology development was later than originally anticipated, the milestone of completion of certain tasks by the end of calendar year 1994 was shifted to mid-1996. A successful program will require a sustained commitment to the total original funding of $262 million, shared equally between industry and government.

Because the additional battery work being funded by the DOE outside of the USABC contracts is vitally important to the potential future efforts of the USABC, it is appropriate to note here that the $1.8 million in funding identified for this work is inadequate and will require a significant decrease in the previous level of effort. This could have serious ramifications for long-term battery technologies as these basic research programs function as "seed money" for generation of the concepts that could eventually make their way into the advanced battery development process of the USABC.

Submitted, on behalf of USABC, by

John R Wallace

John R. Wallace
External Affairs Officer
Management Committee
US Advanced Battery Consortium

March 7, 1994

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CONSORTIUM

Introduction

CARB
PUBLIC MEETING
MAY 12 & 13, 1994

USABC Presentation to the California Air Resources Board
Public Meeting
May 12 & 13, 1994

By
John F. Williams
Chairman USABC

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Purpose

CARB
PUBLIC MEETING
MAY 12 & 13, 1994

USABC

To develop for commercialization advanced battery systems that will accelerate market potential of EVs by improving EV range and performance

Today's Meeting

To provide USABC's perspective on the status of Mid-Term battery technologies to the CARB public meeting

15.00

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Battery Technology Time Line

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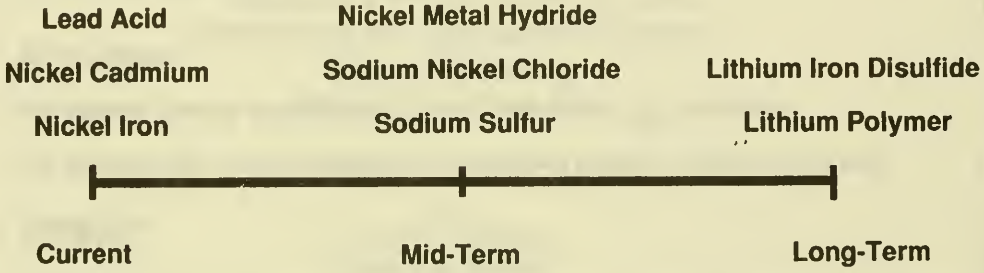
MAY 12 & 13, 1994



Current	Mid-Term	Long-Term
Lead Acid	Nickel Metal Hydride	
Nickel Cadmium	Sodium Nickel Chloride	Lithium Iron Disulfide
Nickel Iron	Sodium Sulfur	Lithium Polymer

14.67 glg

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BATTERY DEVELOPER CONTRACTS

DEVELOPER	TECHNOLOGY	TIMING	START DATE	BUDGET (MILLIONS)
OVONIC	NICKEL METAL HYDRIDE	MID-TERM	5/92	19.9
SAFT	NICKEL METAL HYDRIDE	MID-TERM	12/92	20.7
SILENT POWER	SODIUM SULFUR	MID-TERM	8/93	12.1
SAFT	LITHIUM IRON DISULFIDE	LONG-TERM	12/92	17.3
W.R. GRACE	LITHIUM POLYMER	LONG-TERM	1/93	27.4
3M	LITHIUM POLYMER	LONG-TERM	12/93	32.9
YARDNEY	NICKEL BASED	MID-TERM	1/94	2.5

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BATTERY DEVELOPER CONTRACTS

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DEVELOPER	TECHNOLOGY	TIMING	START DATE	BUDGET (MILLIONS)
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3M	LITHIUM POLYMER	LONG-TERM	12/93	32.9

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Battery Development

A Bottom-Up Process

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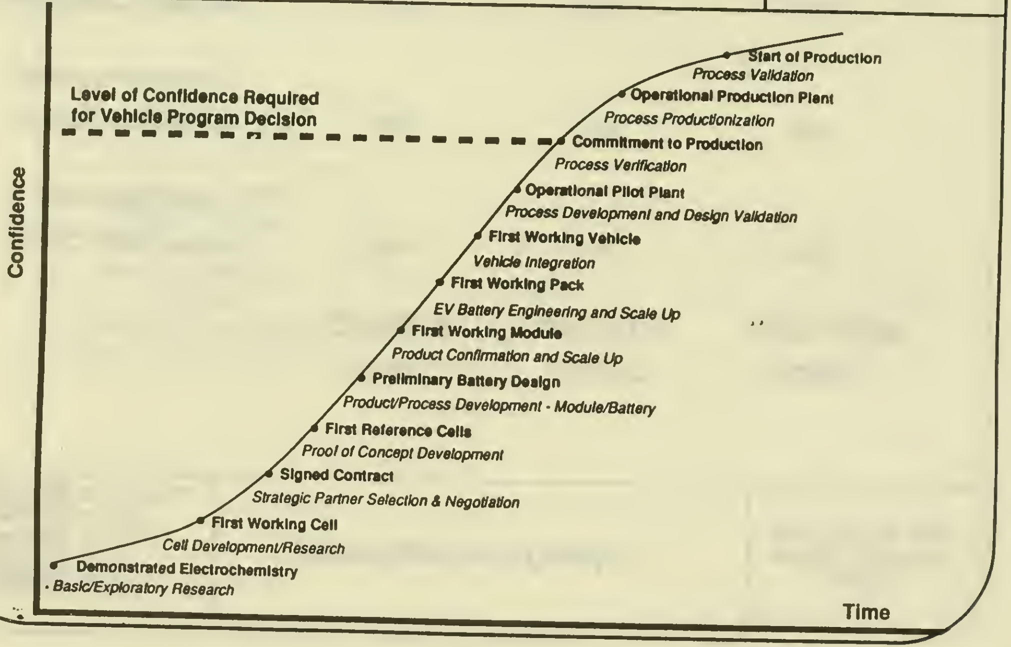

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Development Goals

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	NICKEL CADMIUM	USABC MID-TERM	USABC LONG-TERM
PURCHASE PRICE ($/Kilowatt-Hour)	500	150	100
ENERGY DENSITY (Watt-Hours/Liter)	100	135	300
SPECIFIC ENERGY (Watt-Hours/Kilogram)	55	80	200

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R&D Timing Schedule

Mid-Term Battery Technologies

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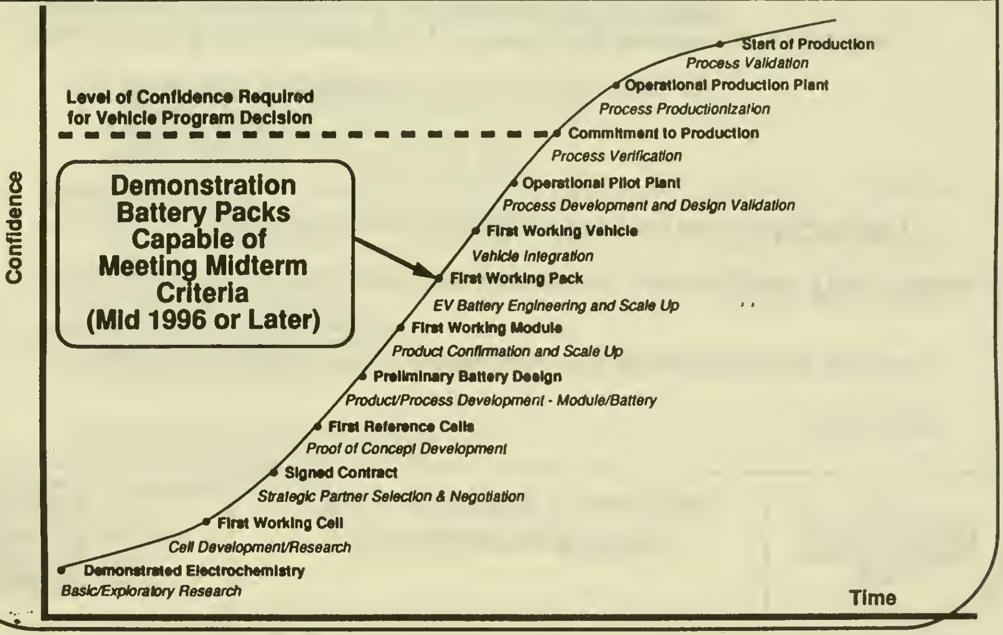

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Development Plan

Mid-Term Battery Technologies

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- Continue Materials and Process Research and Development to Achieve Cost and Performance Criteria
- Produce Battery Pack Deliverables Capable of Achieving Mid-Term Criteria
- Verify Candidate Technology at Mid-Term Criteria (via USABC Battery Test Procedures)
    - Calendar Life
    - Cycle Life
    - Battery Performance
- Main Concern is the Uncertainty of Predicting the Time at which the Candidate Technologies will Achieve Mid-Term Criteria

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Commercialization Plan
Mid-Term Battery Technologies

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- Research and Development- Phased Experimental
  - Laboratory Research & Testing of Cells
  - Product Configuration & Scale -Up
  - Module Design, Fabrication & Test
  - Pack Design, Fabrication & Test .... (Approx.) 30 Units
  - Vehicle Integration & Development
  - Design Verification .... (Approx.) 100 Units

- Operational Pilot Plant .... 2,000 to 5,000 / Year
  - Process Development
  - Process Verification
  - Design Validation

- Operational Production Plant .... 10,000 / Year
  - Process Productionization
  - Process Validation

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Commercialization Timing

Mid-Term Battery Technologies

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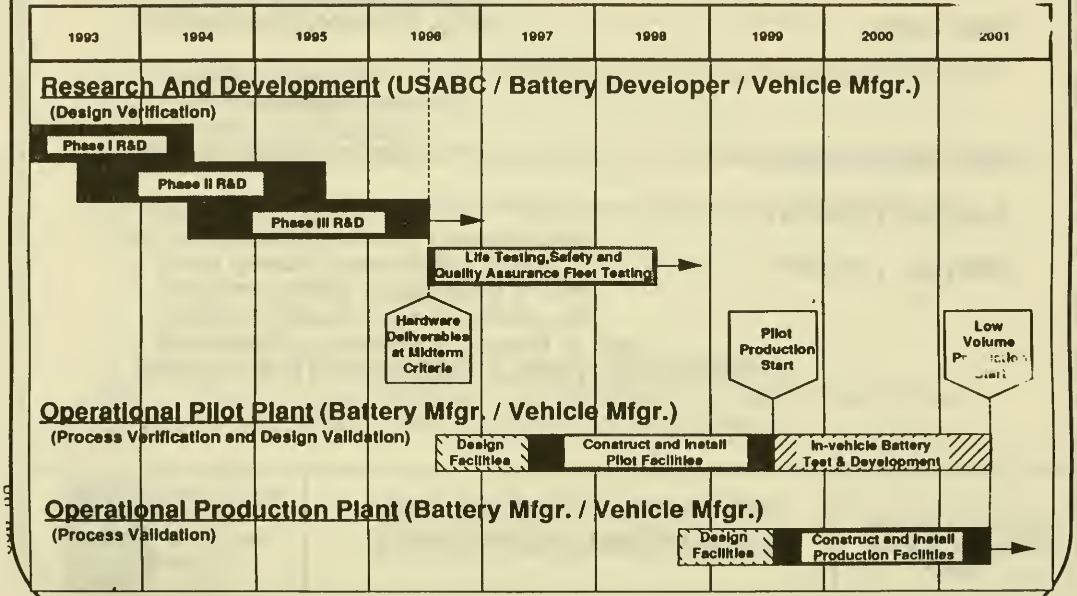

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Summary

Mid-Term Battery Technologies

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PUBLIC MEETING
MAY 12 & 13, 1994

- No Technology is Projected to Achieve Mid-Term Cost Criteria
- Cycle Life and Calendar Life Have Not Been Demonstrated
- Timing Projections:

Expected Date

  - Hardware at Midterm Criteria - ie, Projected Date............... Mid 1996 (Approx. 30 Units)
  - Design Verification - ie, Cost, Calendar and Cycle Life, Safety, Quality etc. (Approx. 100 Units) .... Mid 1998
  - Operational Pilot Plant (2,000 to 5,000 Units per Year)....... Mid 1999
  - Operational Production Plant (10,000 Units per Year)........ Mid 2001

Mr. KLEIN. Thank you. Thank you very much, Mr. Williams.

Our next witness is Mr. Stanford Ovshinsky, president of Energy Conversion Devices.

Mr. Ovshinsky.

Mr. OVSHINSKY. Thank you. Mr. Chairman, Committee, I am appreciative of being here.

Our company has a subsidiary called Ovonic Battery Company, which has been mentioned several times in the discussions today. Since I'm going to be on record with my written testimony, I would prefer to generate questions and to make statements which I feel might be helpful to put in perspective why we're really sitting here.

Are we sitting here for a research and development program? Are we sitting here to promise developments into the year 2000-something? I can only tell you as a scientist, when a scientist tells you that they're going to do something in that length of time, it means it hasn't been invented yet.

What I think we're all here about is that there is a driving force, a dynamic force, in our world society which demands that we have electric vehicles. What I mean by that is that there's information that's recently come out that there's going to be over a billion cars in the first part of the next century with a concomitant increase of pollution. What we have here is a situation getting so out of hand that it must be met because the strategic importance of oil brings on war; it adds to inflation, which causes unemployment; the pollution causes social problems in terms of limiting new industries and affecting the health of people; so we can have a functioning educational system. And, certainly, it affects other problems having to do with the deficit.

Since this is well known, I'd like to go on to the familiar litany of why there can't be an electric car. And, by the way, I am so pleased at the question that was asked by our Representative from Michigan about basic science because the thing that I would like to address as I sit here—not representing a typical battery company as you understand battery companies—battery companies usually produce lead acid, nickel cadmium, nickel iron, you know, that typically use two elements. And it was mentioned here at this table that what we needed to do was to find out how to better use the table of elements, that we aren't going to invent new elements. That's absolutely true.

The reason that I sit here is because our company—and I, particularly, as the primary inventor—from the very beginning with my wife starting in the fifties, decided that there was a new field of science that was necessary to meet and solve these kinds of problems, and that field was to engineer and design materials as one engineers and designs cars, and this meant an entirely new field of science called disordered materials.

In our batteries we have nine, ten, or eleven different elements. We have utilized not the electrochemistry that's typical in batteries. We have utilized the new world of materials science. This world of materials science is serving our Nation very much in terms of—the Department of Energy has recognized us as the leader in the field of photovoltaics by using this approach.

So I couldn't agree more that what we need is a new approach. What's needed most for the electric car, however, is the battery.

The other components will evolve and change with time, but they are very—we all know what to do, what we're going to be doing, and we have at my right hand here one of the most creative people involved in the design of electric drive systems.

I am not going to discuss the ancillary systems. I'm going to discuss the battery, which is a system in itself. And the litany that we've all heard, that we face, that the US governmental representatives face, is that there isn't any range; there isn't any speed. I mean, who would want a car that would go 50, 60 miles? Who would want a car that can't pass another car? Who would want a car that you can't charge in less than six or eight hours? Who would want a car that you have to change the batteries every 20,000 miles, that you can't recycle, et cetera, et cetera? And the answer is, obviously, very few people.

However, who would not want a car that could go over 200 miles, that could be recharged 60 percent in 15 minutes, that would have the speed of a sports car, that the lifetime of the car would be the lifetime of the battery, and that one could recycle without any problems? In fact, it would have no poisonous or objectionable materials in it. Now that's exactly what the Ovonic battery offers. If it was not for the help that we received from the Department of Energy, particularly from the Consortium, my colleague on the left, we would not be able to make these statements with anything more than the certainty of having expressed them, but no one paying much attention to them.

We have been able to build these kinds of batteries, put them in vehicles, and prove these statements are correct. We are approximately within the near term—in fact, we've exceeded some of the specifications of the medium term, I should say, the midterm specifications of the Consortium.

Now what it seems to me to be, that it comes down to, is that the technology is in place. There is a preferred technology. The idea that all technologies are equal is, I believe, a misunderstanding. You either have a technology or, if you have to invent a new one, historically, you're 25 years away from anything commercial.

I believe that not only is our technology, while it's beginning now in the 200-mile range and more, that certainly if I had the investment monies from various agencies of the government, I would certainly be able to promise without any problem that we could double the amount of energy density that we're now saying that we could do, and from then on go on further because we're in our infancy.

You take a mature industry like lead acid or any other battery, incremental changes cost a tremendous amount of money. In our kind of new technology large changes can occur with relatively small amounts of money.

So I sit here as sort of a catalyst to the rest of my colleagues to my left and right. We are an independent company, and we want to go into production. So what are we doing about that? For one thing, we put in the Consortium agreement that we would come up with a manufacturing partner, so as not to just take research and development money and then come back for more money, but to actually go into production and start making batteries that would be placed in electric vehicles to make them realistic. This is exactly what we've done. We are proud to announce, of course, that we are now—we now have what we call GM-Ovonic. We are very exceedingly proud to be associated with Bob Stemple, an exemplary figure in the automotive field. We are serious and dedicated and committed to building the kind of new industry that will be able to fulfill the needs that you've heard expressed today.

Obviously, our position has to be different from those who come forth and say, "on the one hand, on the other, and if and when"; our position has to be, as it was expressed up there, that we are representative of that part of America—I grew up in the Midwest—that says, "it will be done, it can be done, and it shall be done."

So I would rather have my colleagues speak, and answer questions, than take any more of your time. Thank you for your consideration.

[The prepared statement of Mr. Ovshinsky follows:]

TESTIMONY OF STANFORD R. OVSHINSKY

PRESIDENT AND CHIEF EXECUTIVE OFFICER OF
ENERGY CONVERSION DEVICES, INC. AND
CHAIRMAN AND CHIEF EXECUTIVE OFFICER OF
OVONIC BATTERY COMPANY, INC.
BEFORE THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
JUNE 30, 1994

I am Stanford Ovshinsky, Cofounder and President of Energy Conversion Devices (ECD), and Chief Executive Officer of Ovonic Battery Company (OBC). My wife Iris and I established ECD in 1960 to develop new products and technologies based on my inventions and work in amorphous and disordered materials, a field which had been unexplored until that time. In addition to engineering new materials for new products, we concurrently develop the manufacturing process, and build production machines at our machine building facilities. We also establish basic and fundamental patents in the field. This intellectual property is important to us and helps to establish U.S. technology leadership.

We have developed and successfully commercialized many products in this manner, including our proprietary nickel metal hydride (NiMH) batteries, amorphous silicon based photovoltaics, flat panel displays, optical memories, high density computer memories, high performance copier drums, and sensors, to name but a few. ECD has close to 400 US patents and 1900 corresponding foreign patents, with many additional applications pending.

It has long been our firm belief that electric vehicles would develop as a part of the future automotive mix. This important new industry will emerge in response to the worldwide need for cleaner air, as well as America's specific need to reduce dependence on foreign oil, which is detrimental to our national security and economic well being. Confident that the Ovonic NiMH battery would be the key enabling technology for a viable EV industry, we were determined to develop the battery as expeditiously as possible.

We feel our technology is now demonstrating its potential to enable development of commercially viable EVs. Recently, together with General Motors, we established GM Ovonic, a joint company to commercialize and manufacture EV batteries to serve the emerging market for electric and hybrid vehicles.

The government assistance we receive through the U.S. Advanced Battery Consortium (USABC) has been very instrumental in bringing the technology to its present state of development. It was also instrumental in establishing a leadership position and competitive advantage for the U.S. automotive industry in this technology.

Ovonic battery technology, however, like the EV industry itself, is still in its infancy. There is opportunity for very substantial further development ahead, which can both advance the technology and assure continued U.S. leadership therein. Dramatic improvements are available in our technology with relatively modest investment. Continued support from the USABC as well as support from other government programs would enable us to provide a battery technology that could make EVs fully competitive with conventional vehicles in both performance and cost.

I would like to briefly summarize the status of our EV battery development and commercialization program, and then discuss the role of government programs in that process.

BATTERY DEVELOPMENT STATUS

Ovonic Battery Company (OBC) was established as a subsidiary of ECD in 1980, and very substantial investments were made by ECD to develop a new rechargeable nickel metal hydride (NiMH) battery based on new hydrogen storage materials developed at ECD.

OBC's high performance NiMH batteries were initially developed and commercialized in small cell sizes to replace nickel cadmium batteries used in notebook computers, cellular phones and other portable electronic devices. These batteries are in production by OBC's licensees around the world and currently available on the commercial market. Any commercially available NiMH battery is covered by OBC's patents.

OBC has at all times been able to scale up from small size batteries to larger sizes without loss of performance. OBC began to scale up its batteries for use in electric vehicles in 1990. In May, 1992, OBC's EV battery program picked up momentum upon receipt of the first contract awarded by the USABC. OBC is now in the third phase of a three phase program to meet the USABC midterm goals for EV batteries. Performance has been excellent and all technical milestones have been met on or ahead of schedule.

Although the initial USABC contract called for the delivery of prototype batteries at the end of three years, OBC installed the first battery pack in an electric vehicle in August, 1993, eighteen months ahead of schedule. Based on our rapid progress, the USABC placed an order for EV batteries for delivery early this year. These batteries have been delivered and are now being installed in vehicles, and results have been very encouraging.

The Ovonic battery is a robust, balanced performance battery, unique in that it combines the attributes needed for a successful EV battery. Further details describing the Ovonic EV battery appear in an article in the April, 1993 edition of Science magazine.

We have made significant progress in our EV battery program, and our EV batteries are well on their way toward meeting or exceeding all of the USABC midterm goals.

Specific energy is one of the most important battery performance criteria, since it is critical for determining vehicle range on a single charge. The USABC midterm goal for specific energy is 80 Wh/kg. Some of our small size battery licensees are already producing commercial batteries with 80 Wh/kg. In EV batteries installed in vehicles, we have delivered systems approaching the midterm goals.

Even at this stage of their development, our batteries have demonstrated impressive range capabilities. A converted Geo Metro equipped with an Ovonic battery recently travelled a record breaking 214 miles on a single charge during the American Tour de Sol race. This same car won the Arizona Public Service 500 race, finishing the 125 mile course in under two hours, 9 laps in the lead, at an average speed of 65 mph, with energy to spare.

Cycle life is another of the critical performance criteria, as it determines the useful life of the battery and total battery cost over the life of the vehicle. We project that our EV batteries will last the lifetime of the vehicle based on the cycle life of the Ovonic battery demonstrated thus far. The USABC midterm criterion for cycle life is 600 cycles at 80% depth of discharge (DOD). Our significant experience with small batteries in commercial production, as well as initial testing of EV cells and modules, gives us high confidence that this specification will be exceeded.

Power density is another critical factor as it determines acceleration capability. OBC's present power capabilities exceed the USABC midterm goal of 150 W/kg. Prototypes have provided over 400 W/kg peak power. The Ovonic NiMH battery is one of the highest power batteries in existence today, and vehicles that have been equipped with Ovonic batteries exhibit unsurpassed acceleration throughout the entire depth of discharge.

In addition to providing range, power and long life, the Ovonic battery is also maintenance free, completely recyclable, non-toxic, and tolerant to overcharge and overdischarge conditions frequently encountered in high voltage battery packs.

One of the most critical factors, of course, is cost. The midterm goal of $150/kWh was established by the USABC on the assumption that the battery would need to be replaced one or more times during the life of the vehicle. Since the Ovonic battery will last the life of the vehicle and therefore not require replacement, the currently projected cost is well within the life cycle cost goals of the USABC.

We believe a selling price of $150/kWh is achievable in a realistic time frame with adequate funding support. OBC has a detailed development program aimed at reducing materials and manufacturing costs to meet the cost goal while achieving a specific energy 50% higher than the USABC midterm goal. This program will require additional R&D funding from USABC preferably; but if not, from another government source. Improvements developed under the program will not obsolete our manufacturing process. Rather, they can be integrated into the process incrementally as they occur.

Of course, the cost goal is dependent upon getting the battery into high volume production. The Ovonic NiMH battery is unique among advanced battery technologies in that it is already in commercial production for consumer battery applications. The most advanced part of the technology, namely the electrodes and electrode materials, have been in commercial production at OBC for several years. The assembly of our EV batteries, however, has been primarily carried out by hand and limited to prototype production.

We are therefore extremely pleased to have formed a new venture with General Motors, GM Ovonic, to manufacture Ovonic NiMH EV batteries to meet market demands. This manufacturing venture will make EV batteries available to all the partners in the USABC, to EPRI and EPRI participants, to EV conversion companies and to other manufacturers of EVs. The partnership will abide by all the provisions of the USABC contract, which provides for a competitive advantage to the USABC partners. We are very proud to be associated with General Motors in this endeavor. We are also very happy to have the counsel and guidance of Robert Stempel, who is an exemplary figure in the automotive industry.

To summarize, with continued government support, OBC fully expects to meet all the USABC midterm goals. With GM Ovonic, we are in the process of setting up manufacturing facilities for EV batteries incorporating USABC's cost and performance standards as guidelines to the industry which will help accelerate acceptance of EVs and meet market demands.

ROLE OF GOVERNMENT PROGRAMS

Government support has been critical to our program. Our small company would not be where it is today were it not for the USABC contract which was instrumental in enabling us to accelerate our EV battery development program.

Government support was also instrumental in securing a competitive advantage to the US for the use of our battery technology. We tried hard but unsuccessfully in the early stages of development to receive financial support in this country. Financial support we managed to receive from a number of foreign automotive companies helped to sustain our EV battery program before we received the USABC contract. As the world leader in NiMH battery technology with a dominant worldwide patent position, OBC worked hard at that time to preserve the ability to provide American companies with a competitive advantage. Had the USABC contract not materialized when it did, we would have become more dependent on foreign support and no doubt competitive advantages would have been bestowed accordingly.

Our battery technology is still in its infancy. Additional government support will be necessary to meet the midterm cost goals established by the USABC. With adequate R&D support, we believe that our battery can be further developed to meet and exceed USABC long term goals.

The USABC has been a useful mechanism for advancing battery technology, and will continue to be. Indeed, it is the only government program which has supported our battery work thus far. We believe, however, that it is important that other government programs continue to be available to support development work at independent companies such as ours.

For example, EVs are a dual use technology. The DOD EV demonstration program focusses on military applications which can vary significantly from commercial applications. We believe this program not only has a useful mission, but also provides an opportunity for independent companies such as ours to develop other aspects of their technology.

Because our battery technology has a wide range of applications, programs administered by the Department of Commerce would also be appropriately useful in terms of further advancing aspects of the manufacturing technology germane to all applications. This could help assure U.S. leadership in battery technology for everything from portable electronics to utility storage.

The DOE hybrid vehicle program is yet another example of an opportunity we believe could contribute to our battery's full development and U.S. leadership in new automotive technologies.

In summary, we feel that the current programs in EV technology should have increased funding and that a range of new programs supported by DOE and other agencies and focussing on battery research, manufacturing processes and technology development should be established so the successes that have been secured can be built upon.

Government programs have helped the U.S. establish an important leadership position in the emergent EV industry of which we are proud to be a part. We look upon ourselves as a resource to the U.S. auto industry and we look forward to continue working together to maintain and strengthen that leadership, and to reap the environmental, health and economic benefits of this technology.

Thank you.

Mr. KLEIN. Well, thank you very much, Mr. Ovshinsky, for those very, very provocative and thought-provoking remarks.

Our next witness is Mr. James Worden.

Mr. WORDEN. Good morning.

My name is James Worden. I am the CEO and Director of R&D at Solectria Corporation. It is a pleasure to be here today to discuss our company, the state of electric vehicle technology, and the role that the Federal Government can play to help create a viable, competitive electric vehicle industry.

Solectria is a Massachusetts-based high-technology company that develops advanced electric vehicles and components. I founded the company in 1989 with a colleague from MIT with the belief that electric vehicles were both technologically feasible as well as economically viable.

Our production of an electric vehicle, the Solectria Force, was the first advanced electric vehicle available for sale in the United States and is now on the road throughout the U.S. and the Pacific Rim. We currently are introducing a light-duty pickup truck which we are delivering to customers around the country. Over the next two years we will be ramping up vehicle production from just over 100 vehicles annually to over two thousand annually, to meet the growing needs of the fleet market.

Although we are currently a small firm with only 35 people, we have been able to stay out on the forefront of the industry through innovative thinking and perhaps a fresh approach to the engineering challenges facing us. You will find more detail on our company included in the written record. However, I'd like to point out a few company highlights.

Some recent records that we've attained—in February, a Solectria E10 pickup truck using commercially-available lead acid batteries completed 831 miles driving in a 24-hour period using a quick-charge technology. The effort was funded through ARPA's EV program.

In testing at the California Air Resources Board in April, a standard Force GT, using Ovonic's nickel metal hydride batteries, had a range of approximately 150 miles on a single charge in combined city-highway driving, as you've heard. In June, the Force RS, using the same battery technology, completed 214 miles on a single-charge while competing in the Tour de Sol race in the Northeast.

By the way, I would like to point out that the distance records set were in part due to the battery, but also the efficiency of the drive train, the Solectria involvement in the whole vehicle, and the systems integration of the vehicle, which is a key issue with the vehicles.

We strongly disagree with the view that electric vehicles will always be expensive. There's nothing inherent in the electric vehicle that should make it significantly higher in price than the gasoline vehicle. In fact, in volume production, costs should be quite similar.

The Solectria Force currently costs about $26,000. However, please bear in mind that this is virtually a hand-built automobile. As we increase production in the coming years, we hope to bring the effective price down close to $15,000 with Federal, State, and local incentives.

We believe that the EV mandates in the Northeast and California are technologically feasible. While battery development must continue, we are not sitting around for a better battery. Development on all other aspects of the electric vehicle must be pushed as far as possible, which will pay off no matter what the ultimate battery is in the vehicle.

However, we are not looking for cold fusion here, either. The engineering challenges are there, but they are surmountable with support from the Federal Government.

Battery technology has come far in the past few years, thanks in part to the efforts of the U.S. Advanced Battery Consortium. The nickel metal hydride battery developed by Ovonic Battery, with funding from USABC, is quite promising and we look forward to the new venture between General Motors and Ovonic to bring this battery into production. We think the key is to make this technology affordable because it is definitely the most promising battery we've seen. In the interim, we do believe that advanced lead acid batteries can fill the needs of most commuters and fleets.

The electric vehicle business will be a global market. In Europe, Japan, and Southeast Asia, automakers, component manufacturers, and their governments are actively pursuing electric and hybrid vehicle development. In the race to the market, the U.S. may be slightly ahead, but we will fall behind if our efforts aren't focused.

The Partnership for a New Generation of Vehicles announced by President Clinton in 1993 was an impressive statement of the administration's commitment to clean transportation. However, we are somewhat concerned that this partnership is only between Detroit and Washington. In helping the development of a new automobile, it definitely makes sense for Federal agencies to work with the Big Three. After all, they have been making cars for 100 years. However, as ARPA's electric and hybrid vehicle program has shown, there are other firms around the country that can play a pivotal role in our transportation future.

We think ARPA's EV program is an effective model of how the Federal Government can advance technology. What makes ARPA unique is that it has identified key technological challenges and is allowing a wide range of companies to develop solutions. Firms currently doing research range from small companies like Solectria and Advanced Vehicle Systems from Tennessee to industrial giants like United Technologies and Westinghouse, to automotive leaders like Delco-Remy.

The ARPA program manager, Major Richard Cope, who's here, sets aggressive milestones for companies to meet and then sets them free to achieve these objectives. With limited paperwork and overhead requirements, money is going where it should: to technology development. And, as Dr. Denman can confirm, we are getting results.

There is tremendous research going on all over the country that relates to electric vehicles and a lot of companies who haven't even worked in the transportation sector. A major contribution that ARPA is making is bringing these companies together to work toward a common goal of a cleaner vehicle.

Solectria is developing a number of products with the support of the Federal Government. Through the Northeast Alternative Vehicle Consortium, we currently have several programs being funded by ARPA. The most challenging program is the Sunrise Project, co-funded by ARPA and Boston Edison. With technology partners from the automotive, marine, and aerospace industries, Sunrise Program is developing a lightweight, composite electric vehicle which we hope will be the electric vehicle for the late nineties.

The electric vehicle poses unique challenges for designers and manufacturers of automobiles. In a very fundamental way, the EV is different from internal combustion vehicles. The heart of the EV is electronic, not mechanical. Replacing the gasoline engine and its thousands of moving parts that operate at high temperatures is a motor with one moving part and a controller with no moving parts. In a rapidly-changing market, small, fast-growing companies who can adapt and innovate can be quite successful. In a decade, Microsoft grew from a startup to being one of America's most successful companies by beating much larger, entrenched competitors. The EV market offers similar opportunities, and we feel Solectria will be a long- term player in the industry.

Thank you.

[The prepared statement of Mr. Worden follows:]

SOLECTRIA

Statement by

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Before the

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HOUSE SCIENCE, SPACE AND TECHNOLOGY COMMITTEE

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Good morning, Madame Chairwoman and Members and Staff of the Subcommittee. It is a pleasure to be here today to discuss the state of electric vehicle technology and the role that the federal government is playing in making practical Zero Emission Vehicles (ZEVs) a reality. As a small high-technology company competing among "giants" in the automotive world, I think we have a unique perspective on the EV industry and the role that the federal government is playing.

I. Solectria Corporation Background

I founded Solectria Corporation in 1989, along with a colleague from the Massachusetts Institute of Technology. While at M.I.T., I started the Solar Car Program, where we built the first solar powered racing cars in the United States. Solectria was created with the belief that effective zero emission transportation was technologically feasible as well as economically viable. The federal and state initiatives that have been adopted since then have validated that vision.

Solectria's initial efforts were centered around developing advanced components for other electric vehicle manufacturers. However, we soon realized that no one in the industry was producing a technologically advanced EV, and that there was an opening in the market. Despite the fact that we had only a handful of people and no resources, we set about the task of designing and producing an effective EV. We introduced the Force, a Geo Metro conversion, to the market in 1991. The Force has been one of the most successful EVs ever produced, and is now on the road around the United States and overseas.

With the Force, Solectria introduced a number of innovations to production EVs in the United States, including:

- an AC induction drive system
- high energy nickel-cadmium batteries

- all-electric heating and air conditioning
- battery thermal management system
- transmissionless automatic drive
- electric, microprocessor-controlled pre-heating

We think that the success of the Force has proven that small companies can indeed lead the market. Innovative thinking, a willingness to take technology risk, and a strong commitment to research and engineering can overcome many obstacles.

Solectria has grown to 35 people, and is one of the largest producers of electric vehicles in the United States. We have recently added a light duty pickup truck to our product line, which we are now delivering to fleets around the country. Over the next two years, we will be ramping up production to meet the growing needs of the market, from 100 vehicles in 1994 to over 1000 by 1996.

A lot has been written about the fact that EVs cost over $100,000 and will always be expensive. We disagree strongly with this view. **There is nothing inherent in an EV that should make it significantly higher in price than an internal combustion engine (ICE) vehicle.** In fact, given its relative simplicity, it should be comparable in price in volume production. The Force currently costs $26,050 While the price is somewhat high, we think that it is remarkable that we can virtually hand-build a vehicle for such a small amount. As we increase production over the next four years, we expect to bring the price of the Force down to well below $20,000. In fact, with federal and local incentives added in, we hope to reach an effective price of $15,000. Please bear in mind that this is still for a very low volume of production by automotive industry standards (under 10,000 units annually).

Recent Successes

This year, Solectria has set a number of milestones in the EV industry:

- In February, a Solectria E-10 pickup using lead acid batteries and a fast charger drove 831 miles in a 24-hour period, in a record-setting run organized by the Advanced Research Projects Agency (ARPA), the Northeast Alternative Vehicle Consortium (NAVC), and the Southern Coalition for Advanced Transportation (SCAT) and its member companies.
- In March, the Force RS dominated the competition at the 1994 APS Electric 500, completing 125 miles at 65 mph using Ovonic's nickel metal hydride

(NiMH) batteries. In fact, the Force had 5-8 % of its range remaining at the end of the race. This marks the third consecutive year that Solectria has won the event.

- In April, a stock production Force using NiMH batteries had a range of approximately 150 miles in combined city and highway driving in testing by the California Air Resources Board.
- In June, the Force RS achieved a range of 214 miles on a single charge in racing at the 1994 American Tour de Sol, the national solar and electric vehicle championship.

Current R&D Program

Solectria has an extensive R&D program, funded in part by the federal government. In the summer of 1993, ARPA awarded 50 percent matching funding to Solectria for several research projects through the Northeast Alternative Vehicle Consortium (NAVC). Solectria has a $300,000 program (with $150,000 from ARPA) for advanced drive system development. It also received funding for its Sunrise development program.

Project Sunrise

The first phase of the Sunrise program is being jointly funded by Boston Edison and ARPA. The Sunrise is a lightweight composite four-passenger electric vehicle, that we hope will set a new standard for EV range and performance. While the vehicle will have interior seating for four adults and will have comparable or superior crash-worthiness to a traditional steel-bodied car, it is expected to weigh under 1600 pounds.

The Sunrise program is production-oriented; the goal is not to build a one-off concept car that will always be too expensive to produce. A key goal of the program is to find the right combination of materials and processes that will lead to cost-effective production. To achieve this, the Sunrise program has a wide range of technology partners; with leading composite firms from the automotive, aerospace, and marine industries.

II. Technology Assessment

Electric vehicle technology is already quite developed, and is rapidly improving. We are not all sitting around waiting for someone to find the Holy Grail of the ultimate battery.

There are improvements to be made to reduce overall vehicle energy consumption, improve reliability and reduce costs of components. These advances are important regardless of what batteries are being used.

I think the most succinct description of the research areas that need continued development can be found in ARPA's Research Announcement (RA-94-24, the "Green Book") for its 1994 Electric and Hybrid Vehicle Technology Program. Instead of restating what is already detailed rather concisely, I have included the appropriate section of the Green Book as Appendix B.

However, I would like to touch on a few areas of technology. Most of the improvements needed are driven by efficiency. No matter what battery is developed, EVs are likely to have less energy on board than ICE vehicles. Thus, minimizing the amount of energy consumed per mile is of critical importance.

Drive System Technology

Electric vehicle drive system components are quite advanced, offering a high power to weight ratio and efficiencies over 90 percent. While advances are continuing, **we believe EV drive systems will not be an obstacle to EV market penetration by 1998.** There are important improvements to be made (e.g., lowering losses, improving motor torque-speed envelope, new control algorithms); reducing drive system costs may be the most important area of development. We believe that manufacturers will reach acceptable cost and performance targets by 1998.

ARPA is funding drive system development projects by a number of firms around the country, from Solectria to Delco Remy. For a relatively small investment, we think that ARPA will obtain significant tangible products in a relatively short time frame.

We realize that the Department of Energy has a relatively large hybrid and electric vehicle development program, much of which is directed toward drive system development. Unfortunately, we are not familiar with the detail of the projects that they are funding.

Vehicle Energy Load Leveling

We believe that batteries will serve as primary energy storage on EVs in the medium term. However, flywheels and capacitors may play an important role in improving battery life and vehicle range.

In general terms, a battery lasts longest if it experiences a level load; i.e., if a constant low level of current is drawn from it. However, in a typical driving cycle, a battery experiences both sharp drains of energy during acceleration as well as fast inputs of energy during regenerative braking (see the left diagram in Figure 1). Rapid discharging and charging of a battery is rather inefficient, with energy being lost in heat rather than being transferred to mechanical energy, and this may significantly reduce the battery's life.

Supercapacitors and flywheels offer a solution to this problem. Instead of drawing energy from the battery during acceleration, the vehicle drive system would draw power from the supercapacitor or flywheel instead. During regenerative braking, energy would also be put back into one of these energy storage devices. The battery itself would experience a relatively constant load. Because charge/discharge efficiencies of supercapacitors and flywheels are high, overall vehicle range would be higher. Battery life may be increased by a factor of two or three.

Supercapacitor and flywheel development is currently going on, funded by ARPA and perhaps by other agencies as well. Research in both areas is perhaps as important to EVs in the long term as improvements in batteries themselves.

We believe that supercapacitors may offer a more cost-effective short to medium-term load leveling answer than flywheels. This may reflect our bias toward electronic solutions over mechanical ones. However, we think the technical obstacles to building a cost-competitive flywheel (a highly complex mechanical device) may be more daunting than the development for a supercapacitor (essentially a "dumb" electronic part with no moving parts). In fact, Solectria recently completed a project with the Idaho National Engineering Laboratories to develop an electronic interface to allow the use of supercapacitors in an electric vehicle.

Battery Technology

There has been considerable evolution in battery technology in the past two years. The most attractive battery technology that we have seen to date has been Ovonic's nickel metal hydride battery. While higher energy density (amount of energy per unit of battery weight) is important, a longer cycle lifeequally as critical. An EV is much more feasible if batteries last the life of the vehicle. As Stanford Ovshinsky of Ovonic has discussed, the nickel metal hydride battery offers high power density and energy density, but also a long life. In March, a Solectria Force with Ovonic's battery was able to travel for 125 miles at 65 miles an hour at the APS Electric 500 in Phoenix, AZ, and traveled 215 miles on a single charge at the American Tour de Sol in the Northeast in June.

We are looking forward to the results of the manufacturing agreement between Ovonic and General Motors that was announced in recent weeks. We hope that the two parties will be able to find a way to bring the battery technology to market at a cost-effective price.

While we commend the efforts of the U.S. Advanced Battery Consortium in funding companies like Ovonic and others who may offer a long term battery solution, we would also suggest that further research be directed to batteries that are closer to market. In the next 2-3 years, lead acid batteries appear to be the most viable alternative. Indeed, **to meet the needs of typical urban fleets, the ranges offered by lead-acid batteries appear to be sufficient.** However, lead acid batteries do need continued development resources, to improve life and reliability.

Materials Research

Reduction in weight of electric vehicles without compromising safety would significantly improve EVs. Lowering chassis weight means that the propulsion system can be lighter, and a smaller battery pack can be used; in essence, a ten pound reduction in chassis weight can mean a thirty pound reduction in overall vehicle weight due to this multiplier. Use of lightweight structural composite materials instead of metal may provide the answer.

Although the automotive industry is making increasing use of composite materials in vehicles, they are primarily being used for body panels and non-structural members (with certain exceptions).

The technical challenges are to allow the introduction of composite primary structures into electric vehicles at marketable automotive costs (in the range of $2-$5/lb.) In the aerospace sector, extensive use is made of structural composites; however, the tolerable cost ranges from $100-$1000/lb, and the shapes fabricated are relatively simple. In any given aircraft model, production rates range from only tens to hundreds per year. In the automotive sector, not only are acceptable price points markedly different (around 100x), but the applications require a wide variety of complex shapes in volumes ranging from tens to hundreds of thousands per year.

While composite car bodies can have high strength characteristics, they will react differently in an impact than conventional metal bodies. However, the existing tools for doing finite element modeling of crashes (e.g., Dyna 3D) have been developed for the crushing of metal structures. Developing and validating an effective model to predict the crushing of composite structures is crucial to the development of lightweight composite vehicles.

We hope that Solectria's Sunrise program will take some steps in developing solutions to some of these questions. However, we would like to see significantly more federal resources devoted to the technical issues involved. While reducing vehicle weight is of special concern to EVs, it also has an important role in ICE vehicles. It is estimated that a 25 percent weight reduction in ICE vehicles would result in a gasoline savings of 750,000 bbl/day, or 13 percent of current U.S. gasoline consumption. Lower weight does not have to mean reduced safety; composite vehicles can be as strong or stronger than traditional metal cars.

ARPA has identified most of these issues with composite vehicles as target areas in its 1994 program, and is currently seeking proposals to answer these challenges. While there are also programs at the National Institutes of Standards and Technology (NIST) and the DOE, these are primarily with the Automotive Composites Consortium (ACC) and the U.S. Council for Automotive Research (USCAR). The efforts at these agencies appear to be closed off to companies outside of the Big Three automakers, so it is difficult for us to evaluate how resources are being allocated.

III. The Role of the Federal Government

We applaud the strong initiatives that the Congress and the Clinton Administration have taken to accelerate the development of automotive technologies in general and electric vehicles in particular. Most of our work to date with federal agencies has been with ARPA, although we have benefited indirectly from research funded by the U.S. A.B.C. and the DOE Site Operator Program.

ARPA

In the short time that ARPA's Electric and Hybrid Vehicle Program has been in existence, we have been amazed at the speed at which development has happened. Not only has ARPA funded work that we consider to be significant, but it has also helped develop an entire industry. Through six regional consortia of high technology companies, utilities, and government agencies, there is tremendous networking and joint product development. We think ARPA's program is unique in that it has identified key technological challenges and is allowing a wide range of companies to develop solutions to them. Firms currently doing funded research range from high-tech startups like Solectria and Advanced Vehicle Systems to industrial giants like United Technologies and Westinghouse to automotive leaders like Delco Remy. ARPA realizes that all knowledge about transportation may not lie in Michigan, and in fact may come from players outside the traditional automotive industry.

ARPA's program is also unique in that it is administratively lean. Companies have aggressive performance milestones to meet, and beyond that have a great deal of freedom. This allows the bulk of the project resources to go where it should--technology advancement--rather than into overhead and paperwork. The ARPA Program Manager, Major Richard Cope, has also been active in trying to open up lines of communication among companies performing work and groups within the federal government who have knowledge to contribute.

We would like to take this opportunity to congratulate ARPA on what it has been able to accomplish in its RA 1993 program. With a relatively small budget spread among a large number of firms, it is achieving concrete tangible results.

Recommendations for Federal Government

We would like to see ARPA's program serve as a model for how the federal government should devote its resources. It is in the interest of the federal government to fund technology development that has a degree of risk but that has large potential return. Electric vehicle technologies are a great example. We are in a race with Europe, Korea, and Japan. EVs are a potential world market; this is not just happening in California. In fact, the market that is most ripe for EVs may be Southeast Asia and the Pacific Rim. While the United States has a technological lead, it is one that is closing. While there are many in industry who say that electric vehicles are not feasible, the fact of the matter is that they **will happen**.

The federal government is correct in targeting ZEVs as a area for technology investment. Notwithstanding the recent data mentioned in the press, electric vehicles do provide considerable air quality benefits, and help promote energy independence. Equally important, they represent an important new long-term market opportunity. However, we believe that the federal government must be open to the possibility that there are a wide range of companies who can play a role in developing clean cars for the future.

General Motors, Ford and Chrysler have tremendous research and engineering capabilities, and have repeatedly proven themselves capable of meeting technological challenges. However, electric vehicles are substantially different from traditional internal combustion engine (ICE) vehicles. The heart of an EV is electronic, not mechanical. Replacing a gasoline engine and its thousands of precisely engineered moving parts, operating at high temperatures, is a motor, with one moving part, and a controller, with no moving parts. It requires a new set of suppliers, and perhaps a different vehicle assembly process. Are the Big Three uniquely qualified to produce them? Perhaps.

However, perhaps not. It is possible that there will be a new set of firms who will supply parts for electric vehicles. Perhaps Motorola will be the EV drive system manufacturer of the future; it may be Solectria. It could be that a current composite parts producer, like a Dow U.T. or Ciba Geigy or GE, will be the car body builder of tomorrow. At the very least, the federal government should stay neutral to the issue.

The Clean Car initiative announced by President Clinton in 1993 was an impressive statement of the Administration's commitment to clean transportation. The Partnership for a New Generation of Vehicles (PNGV) headed by Dr. Mary Good may lead to some significant breakthroughs in vehicle development. We would urge that this partnership be a national effort, rather than one between Detroit and Washington. In making resource decisions on electric and other vehicles, it makes sense for federal agencies to work with Detroit; after all, they have been building cars for a hundred years. But as ARPA's program has shown, there are other companies around the country that can play a role in shaping our transportation future.

Small, fast-moving entrepreneurial firms have had a impressive record of success of advancing technology in recent years. In a decade, Microsoft Corporation grew from a startup to one of America's most successful companies by beating more entrenched competitors in a rapidly changing market. MCI grew from a niche upstart to challenge the giant AT&T. In a fast-moving business environment, smaller entrepreneurial companies are able to innovate faster and take greater technological risk. The EV industry may be the same. When the dust settles, the large automakers may indeed dominate the world of zero emission vehicles. However, we feel confident that Solectria will have a pivotal role to play.

Appendix A

Solectria Corporate Overview

Solectria Corporation is a Massachusetts-based company that designs, develops and produces electric vehicles. It also produces a wide range of advanced components for solar-electric and hybrid vehicles ranging from solar race cars to electric transit buses.

In October 1991, Solectria delivered its first production electric car, the **Force** (a Geo Metro conversion) to the Arizona Public Service utility. Since then, Solectria has sold **Forces** and **E-10** conversions, primarily to electric utilities, corporations and public agencies in the U. S. and overseas. **Solectria vehicles are on the road in 16 states and 5 countries. Solectria currently has an order back-log of over 50 vehicles.**

In addition to its production vehicles, Solectria is also a leading manufacturer of advanced drive systems and other components for solar-electric and hybrid vehicles. Components manufactured by Solectria are in use by over 100 customers around the world, including several major auto manufacturers.

Electric vehicles have three major parts: the motor, the electronic components and the battery pack.

- Solectria is an industry leader in the development of electronic controls for electric drive systems. Its motor controllers are over 98 percent efficient. Because of that, Solectria was chosen to develop a hybrid trailer for the U.S. Marines. For the Idaho National Engineering Laboratories, Solectria is developing electronic controls to allow the use of supercapacitors in electric vehicles.
- Solectria is working with battery manufacturers in the United States, Europe and Asia to test and evaluate new battery technologies. In fact, six battery companies are using the Force as an ideal test bed. To determine the best batteries to use in vehicles being delivered to customers, Solectria has undertaken a year-long study of available lead-acid batteries, conducting FUDS cycle testing seven days a week on ten batterie arrays at once. Solectria's chargers automatically shut off after the batteries reach full charge and we have incorporated a safety feature that prevents the car from moving when it is connected to the power source.

The electric vehicle and its market are evolving rapidly - spurred on by environmental and pollution concerns as well as the desire to reduce America's dependence on petroleum. Government regulations at the federal, state, and regional level are pushing the development of technologies as well as the penetration of zero-emission electric vehicles into the marketplace.

Solectria puts great importance on moving forward aggressively and maintaining its technical lead in the EV market at the passenger vehicle, light truck, component and R&D levels. In 1994, Solectria expects to significantly ramp up its vehicle production capabilities, setting up a new 60,000 square foot dedicated assembly facility. Solectria is also aggressively pursuing new technology development, to remain on the forefront. The company has secured over $1.2 million from the Advanced Research Project Agency and matching organizations for grounds-up vehicle and component development, and expects to expand on its R&D efforts over the coming years.

Company History

Solectria Corporation was founded in 1989 by James D. Worden and Anita V. Rajan, two engineers from the Massachusetts Institute of Technology with a long track record of designing and building solar and electric vehicles. Mr. Worden was a pioneer in the development of solar-powered vehicles, building the first solar racing cars in the U.S.

Over its first two and a half years of operation, Solectria designed many proprietary electric drive components. It also developed several prototype ground-up electric vehicles, which it raced to considerable success at alternative fuel and solar-electric racing events around the world. Over that period of time, Solectria sold a broad range of lightweight, high-efficiency components, including motors, motor controllers, and amp-hour counters, to hobbyists, schools and universities, and other EV manufacturers around the world.

In October 1991, Solectria delivered its first production electric vehicle, the Solectria **Force**, to the Arizona Public Service utility. The Force was the first advanced electric vehicle available for sale in the United States. Since then, Solectria has delivered more than 50 **Forces**, primarily to electric utilities and government agencies around the country. In May 1993, Solectria introduced the **E-10**, an electric S-10 pickup truck, using Solectria's advanced drive system technology. The Mid-America EV Consortium, the Northeast Alternative Vehicle Consortium, Vermont Power and Delco-Remy have all bought **E-10s**. Solectria has a consistent production order back-log of about 50 vehicle contracts. Soon, it expects to be able to make sales to the general public, in distinct urban areas that are highlighted as urgent or severe in the Clean Air Act.

In 1993 Solectria won Advanced Research Projects Agency (ARPA) grant moneys and matching funding totaling $1,200,000 to develop a high performance, ground-up production prototype EV (to set a new standard of performance for electric vehicles), as well as for further R&D in AC drive systems. This funding was received through the Northeast Alternative Vehicle Consortium (NAVC), a regional consortium of government agencies, utilities and research firms.

The Force

Solectria has achieved its objectives of a safe and affordable zero-emission vehicle with the **Force**, assembled on a Geo Metro chassis. Combining advanced technology and energy efficiency with reliability and the ease of use, there is simply no other choice than the Solectria **Force**.

The **Force** has been developed and perfected to meet even more than the required quality and safety standards for EVs. It has the highest performance of any production electric vehicle available and is currently undergoing a final round of crash testing at a national testing lab to remove available exemptions and assure users that it is as safe as, or safer than the vehicle from which it was converted.

The Force has been tested by CARB (California Air Resources Board) on a Federal Urban Driving Schedule where it completed twice as many miles as its nearest competitor. CARB had this to say:

> **"The heart of the Force is in the controller, motor and charger. Developed by Solectria, these components combine high efficiency with low weight to produce an EV with the most impressive range and performance character-istics of any currently available production EV of which CARB is aware."**

Following are but a few of the innovations in electric vehicles on the market that were introduced in the Force:

- AC induction drive system
- All electric air conditioning and heating
- Nickel-cadmium batteries
- Battery thermal management system
- Automatic pre-heating

The **Force** offers all the creature comfort options we expect: AM/FM stereo radio, air conditioning, heating, cruise control, power assisted brakes. And some options we don't expect: regenerative braking (standard on all models), car mounted solar panel system, super charger and a power saver control (maximizes battery life and driving range). For customers in the Northeast, Solectria has developed a proprietary thermal energy management system, which mitigates the effects of cold weather on batteries. Delivery is 30-60 days after order is placed with a down-payment.

Solectria has dominated electric vehicle racing in the United States in the 1990s. In March 1993, Solectria took first and third place in the APS Solar and Electric 500, for the second year in a row. In May, Solectria dominated the American Tour de Sol, the U.S. solar and electric championship, winning for the fourth consecutive year. The Force RS completed a record 180 miles on a single charge. In February 1994 the E-10 truck set the World EV 24-Hour Distance Record by going 831 miles on charges of less than 20 minutes each. This record eclipsed the previous one by 30%!

Most recently, the Solectria Force RS took first place at the 1994 APS Electric 500, completing 125 miles at an average speed of 65 mph, using Ovonic's nickel-metal hydride batteries. At the end of the race, approximately 10 percent of the battery capacity remained. Finishing second was Crowder College, also driving a Solectria Force RS. Finishing several miles behind was the University of California Davis, driving a U.S. Electricar Prizm using the Hughes Dolphin drive system.

In June, the Force RS achieved a range of 215 miles on a single charge while competing in the 1994 American Tour de Sol.

Solectria is the only private company selected by the California Energy Commission to participate in the Advanced Electric Vehicle Demonstration Program. **Unlike the 3 other companies chosen** (Ford, Chrysler and Volkswagen), **Solectria offers a product that is both affordable and in regular production.**

Solectria is currently producing and delivering Forces to utilities across the country, universities and other academic institutions, state organizations, corporations, and individual consumers. Our customers list follows. Examples are: Arizona Public Service, Boston Edison, Delco-Remy, Mid-America Consortium, Nevada Power, Northern States Power, Pennsylvania Power & Light, the Sacramento Municipal Utility District, Southern California Edison, Vermont Power and Virginia Electric Power. Many of our customers are repeat customers with our largest, Boston Edison, owning a fleet of vehicles. **Solectria Forces are on the road in 16 states and 5 countries.**

This is an excellent and affordable conversion car, with **base prices starting at $26,050**, normal driving **ranges of between 50 and 130 miles** (depending on battery and options), and and a top speed of 70-75 miles per hour.

Technology

Solectria is the technology leader in the electric vehicle industry. All models of the Force use high-efficiency AC induction motors, with regenerative braking. Our motors and motor controllers operate together at efficiencies above 90 percent. The Force used only 210 AC watt-hours a mile in extensive road-testing by Southern California Edison, and only 140 watt-hours a mile traveling at a constant 35 m.p.h. in testing at the American Tour de Sol!

Solectria is committed to advanced technology. In fact, Solectria's engineers are able to design, engineer and manufacture advanced AC and DC drive systems to meet a variety of specialized applications. We have components in use in vehicles ranging from lightweight solar race cars to electric transit buses.

The Force uses 30% less fuel at the power plant than a similar sized gasoline automobile. Emissions released from a power plant are significantly cleaner in most ways than those from the average tailpipe. It is also much easier and cost effective to control pollution at a single source rather than multiple sources.

Solectria is committed to using the best available battery technologies on the market. To date, we have sold vehicles to five companies doing advanced battery research, and we continue to test and evaluate the batteries on the market. In 1992, the company began the Solectria Battery Testing Program, an in-depth evaluation of the leading available batteries. In the laboratory, Solectria has a computer controlled system that conducts Federal Urban Driving Schedule (FUDS) testing on 10 battery types at once. This data has been used to determine the battery choice in the Force.

Handling

The Force has been designed for superb handling. It uses a new Geo Metro body, which has one of the smallest turning radiuses of any vehicle. A large problem with most electric vehicles produced is weight. Other manufacturers tend to load a vehicle down with batteries and usually exceed the gross vehicle weight of the body they use. The **Force**, on the other hand, weighs between 2050 and 2150 pounds (depending on the model) and remains between 350 and 450 pounds below the Geo Metro's gross vehicle weight. Batteries have been divided between front and rear to optimize driving performance and maintain a low center of gravity. This results in a vehicle that is light and easy to handle, with the feel of the road of a conventional gasoline-powered vehicle.

Ease of Use

The **Force** is available in three models with automatic transmission. Anyone can learn to drive it in a few minutes. The Force features push-button Forward/Reverse/Neutral commands. An electric heater/defroster is standard, as is regenerative braking.

Charging the **Force** is as simple as plugging it in. The **Force** with lead acid batteries comes standard with an onboard 110V AC charger, which will fully recharge the car in eight hours. As it draws only 10 amps, it can be plugged into any household outlet. Charging is accomplished by attaching an extension cord to a plug located in the "gas cap". It is as simple as that. We also offer a 110V supercharger, that will charge the car in four hours (requiring a 20 amp circuit.)

Our newly redesigned 110V charger is completely automatic; it turns on when charging is needed and shuts off automatically when the batteries are fully charged. It is microprocessor controlled, and can be easily changed to fit any required charging topology.

Options

Solectria believes that the consumer should not have to sacrifice creature comforts when driving an electric vehicle. To that end, we offer a wide array of optional equipment beyond our impressive standard features, including air conditioning, AM/FM stereo cassette, power brakes, and cruise control. Also available are hood and roof mounted solar panel systems (for additional range), a thermal management system (for cold regions) and an off-board solar charging station.

Support/ Service

Solectria is committed to providing a high level of service to its customers. As part of every vehicle sale, Solectria provides an on-site training session for the customer's support staff, and offers an extensive warranty. Because all of the electric components in the vehicles are designed and built by Solectria, with our excellent quality control, our engineers can answer all of your technical questions and concerns. Solectria expects to maintain its distinction as the producer of the most viable electric vehicle on the market. In EPRI's Survey of Electric Vehicle Activities 10/92, **electric vehicle fleet owners rated the Solectria Force highest of all in satisfaction and performance.**

The Future

The Force is consistently being refined and upgraded. For 1994, Solectria has made several improvements to solidify the Force's reputation as the market leader:

- All 1994 models feature a CFC-free HFC 134A air conditioning system
- The power of the base model Force has increased by 50 percent, with no increase in price
- By summer, elimination of the vehicle drive belt, directly integrating motor and transmission.
- Achieving full NHTSA certification as part of the 1995 Force

Research & Development Program

Solectria is an engineering-driven company, with a commitment to technology development. The company has several significant R&D programs in the field of electric transportation:

- The company has a joint research project with Arthur D. Little on cold weather optimization of electric vehicles.
- With Charles Draper Laboratories, Solectria is working on production techniques for use of advanced composite materials in vehicles.
- For the Idaho National Engineering Laboratories, Solectria is developing the electronic hardware that will allow the use of supercapacitors for load-leveling batteries in electric vehicles.
- Solectria has developed a hybrid propulsion system for the U.S. Marines, which will be used on a trailer towed by light assault vehicles.
- In the summer of 1993, Solectria was awarded $1.13 million by the NAVC to develop a four-passenger composite electric vehicle prototype. The project is co-funded by ARPA and Boston Edison.
- Solectria has also received ARPA funding through the NAVC to develop a new advanced AC induction drive system.

Electric Truck Conversion

Solectria Corporation unveiled its newest addition to the regular production vehicle line, a converted S-10 truck, called the Solectria **E-10**, at the start of the 1993 American Tour de Sol solar andelectric car race in Boston. This pickup truck is the first available truck that uses an advanced, high efficiency AC induction drive system. It features push-button Forward/Neutral/Reverse commands, regenerative braking, an onboard lightweight 120V AC charger, and a host of other features.

Says James Worden, Solectria's CEO and Director of R&D:

> "We feel that our **E-10** vehicle represents a significant step beyond other electric utility vehicles currently on the market. It will be the new vehicle of choice for institutional customers around the country that are facing mandates to add zero-emission vehicles to their fleets."

The Solectria **E-10** pickup features no transmission at all. Its two AC induction motors directly drive the vehicles rear wheels. Because of this, the vehicle is incredibly simple to maintain and operate. Eliminating the transmission means no gear shifting and no maintenance worries. Equally important, it makes major gains in vehicle efficiency.

Solectria's **E-10** is significantly more efficient than other electric pickup conversions that have been built. With a top speed of 65 m.p.h. and a range of 50-75 miles, although it has been driven to 98 miles on a single charge, the batteries are placed to maintain a low center of gravity, allowing ease of handling and not reduce cargo space at all. It is available motor options providing either 56 or 68 HP, and goes 0-30 in about 8 seconds.

Standard equipment includes: High-efficiency AC induction Drive System, featuring automatic transmission and regenerative braking; power assisted brakes; power steering; electric resistance heater/defroster, DC-DC converter (32A, 12V); onboard Battery Charger (2 kW, 110V AC), and sealed no-maintenance lead acid batteries (14 kWhr, 60 mile range).

Options include: AM/FM stereo radio/cassette; air conditioning; Power Saver Control (maximizes range and battery life on economy setting, maximizes power on normal setting); cruise control; Automatic Battery Thermal System (for top performance in cold climates); Nickel Cadmium batteries (100 mile range); and an onboard battery charger upgrade (3kW, 220VAC required for Ni-Cad batteries).

Delivery is approximately 60-90 days from receipt of deposit.

The **E-10** pickup adds another vehicle to Solectria's impressive product line. The Solectria **Force** has been one the most successful electric vehicles ever introduced and the Solectria **E-10** truck is sure to follow.

A SELECTION OF SOLECTRIA'S ACADEMIC CUSTOMERS

Arizona State University
Auburn University
California Polytechnic Pomona
California Polytechnic SLO
California State Univ., Fresno
California State University, LA
Camden High School
Champlain College
Clarkson University
Colorado School of Mines
Colorado State University
Concordia University
Conval High School
Cornell University
Crowder College
Dartmouth College
Delta College
Drexel University
Ethel Walker School
Florida Institute of Technology
George Washington University
Hacienda La Puente USD
Hawaii Preparatory Academy
Iowa State University
Jordan Energy Institute
Kamehameha School
Lockerby Composite School
Mankato State University
Massachusetts Institute of Technology
McGill University
Michigan State University
New England Institute of Technology
New Hampshire, The Technical Inst.
New Mexico Institute of Technology
Penn State University
Queen's University
Randolph High School
Rochester Inst. of Technology
Roosevelt High School
Rose Hulman Institute of Technology
Saint Johnsbury Academy
Salisbury School
Seattle University
Stanford University-SHARP
Stanford University-Solar Car Project
Texas A&M University
Texas Tech University
Tufts University
University of Alberta
University of California, Irvine
Univ. of California, Santa Barbara
University of Massachusetts, Lowell
University of Michigan
University of Minnesota
University of Missouri, Columbia
University of Missouri, Rolla
University of North Texas
University of Ottawa
University of Puerto Rico
University of Texas, Arlington
University of Texas, Austin
University of Waterloo
Virginia Polytechnic Institute
Waterbury State Tech. College
Webb High School
Western Michigan University
Western Washington University
Winston High School

A SELECTION OF SOLECTRIA'S FORCE AND E-10 CUSTOMERS

Arizona Public Service
City of Davis, CA
Farm Power (U.K.)
New England Electric
Orcas Power & Light
Potomac Energy Power Company
Sierra Pacific Power
Vehicle Research & Test Center
York Technical College
Johnson Controls
NY State Energy Research & Development Authority
McClellan Air Force Base
Boston Edison Company
City of Riverside, CA
Nevada Power
Northern States Power
Pennsylvania Power & Light
Sacramento Utility District
Southern California Edison
Virginia Electric Power Co.
Private Companies (3)
Ovonic Battery Company
GP Batteries
Commonwealth of Massachusetts

Project Sunrise

Solectria's founders have been developing ground-up electric vehicles for almost ten years, both while in academia and at Solectria. While these vehicles were never geared for production, they provided a substantial base of knowledge on the use of light-weight materials and the overall design and efficiency optimization of an electric vehicle. Vehicles like the Flash and Lightspeed proved the substantial improvement in performance and range that could be obtained by moving to a ground-up composite chassis.

In the summer of 1993, Solectria was awarded funding through the NAVC from the Advanced Research Project Agency (ARPA) to finally develop a production-oriented, ground-up composite vehicle. With matching funding from Boston Edison, the total funding for the first phase of this project is $1.13 million. Project Sunrise will last over eighteen months.

Key goals of the project are:

- Design for FMVSS certification
- Advanced thermal management for batteries and passengers
- Production-oriented design

A wide range of technology partners from the automotive, aerospace, and marine industries are involved with the Sunrise program.

APPENDIX B

FOR INFORMATION ONLY

ARPA

Advanced Research Projects Agency

Electric and Hybrid Vehicle Technology Program

Research Announcement (RA) 94 – 24

Proposer Information Package

Major Richard Cope, USMC
Advanced Systems Technology Office
fax (703) 696–8401
email: ra94–24@arpa.mil

FOR INFORMATION ONLY

Power Switch Technology. The multibillion-dollar market for advanced semiconductor power switches includes power conditioning for utilities, electric motor control for industrial applications, electric motor control in ship propulsion, and many other applications where electric power is conditioned. Market forces outside of the EV and HEV community will drive the development of advanced power semiconductors. It is critical that U.S. industry establish a leadership position with emerging power semiconductor technologies.

Emerging technologies include the general application of mosfet-controlled thyristors (MCTs) and the new semiconductor material technologies, including silicon carbide and diamond film. U.S. manufacturers currently offer MCTs at a rating of 65 amps and will likely offer devices at more than 100 amps within the next year. Various devices using silicon carbide material are currently being developed but are not yet commercially available.

The U.S. military has a need for power semiconductors with the following performance characteristics:

Operating Voltage	To 2500 VAC
Operating Frequency	Above 40 kHz
Operating Temperature	Above 200°F
On-Voltage Drop	Low
Power Density	High
Cost	Competitive with current IGBTs (insulated gate bipolar transistor)

The military requirements are extreme relative to those of a commercial EV or HEV, yet may be similar in some areas with the requirements of the electric utilities.

ARPA is interested in receiving proposals that perform one or more of the following technology development functions:

- Apply advanced power semiconductors in EV or HEV control systems.
- Develop key technologies required to enable manufacture of advanced power semiconductors.
- Research material characteristics that are critical to advanced power semiconductors.
- Perform R&D or engineering studies on the characteristics of advanced motor controllers that would result from projected improvements in power semiconductor technology.

Proposals under this element are limited by the practical allocation of funding. Offerors may wish to consider key demonstrations, critical technology investigations, and specialized R&D work.

Advanced Motor Controllers. A variety of controllers exist for induction, permanent magnet, and DC vehicle propulsion motors. Existing commercial controllers vary in cost and efficiency depending on motor type. Low-volume AC induction motor controllers range in cost from $150 to $400 per kW or more. Efficiencies and regenerative capabilities of these controllers vary widely.

Nearly all existing controllers for AC motors include rotor position feedback signals for vector control. The cost of an AC induction motor propulsion system is often driven by the cost of the controller.

Brushless DC (permanent magnet) motor controllers are available from various sources at prices from $75 to $400 per kW. These controllers have also been optimized for efficiency and regenerative power control.

Variable output frequency control for induction and brushless DC motors include various pulsewidth modulated (PWM) and resonant converter designs. Higher performance controllers are closely matched to a particular motor design. Development of additional generic controllers is not desired. New controller designs should be focused on areas that allow a clear improvement over existing state of the art controllers. It is anticipated that successful proposals will consider advanced components, new controller designs, new control approaches, improved controller/motor matching, and control methods that expand the speed/torque envelope.

Losses in existing controllers include conduction losses through power semiconductor switches, electrical losses in capacitive/inductive circuits, motor heating losses induced by harmonic distortion in the voltage supplied to the motor, and losses associated with inadequate motor control. The efficiency of motor controllers is of particular importance to the military since the rejection of heat from the controller is a limiting factor in reducing the volume of controllers.

In-service losses due to harmonic distortion, capacitive/inductive circuits, and inadequate motor control are generally underestimated by steady-state dynamometer testing of EV components. Designers of motor controllers and motors must identify loss mechanisms within controllers or motors and present evidence to improve efficiency through innovative methods. Evidence of in-service losses ascribed to controller performance should be sought in data from supported laboratory testing or other on-road performance. Motor controller development projects that are not supported with efficiency improvement data or loss-mechanism data will not be highly considered.

High Speed-Torque Envelope Motors. Commercial and military needs for drive motors are different. Military systems must have very high power and torque density to meet vehicle performance objectives. Commercial systems also require good power density but must be produced at costs that are competitive with existing automotive propulsion systems. The total area under the torque-versus-speed curve of a military traction motor may be several times the corresponding area under the torque-versus-speed curve of a commercial motor with the same continuous power rating. Although top speeds and horsepower per ton of vehicle weight may be similar in commercial and military systems (e.g., 60 mph and 25 horsepower per ton), the military vehicle must be able to climb a 60-percent grade while the commercial vehicle is generally limited to 20-percent grades.

The power density of available motors is approximately 0.7 kW/kg for 200 to 350 volt commercial motors (peak power rating). The power density of modern military traction motors exceeds 1 kW/kg and voltages may be 750 volts or more. AC commercial traction motors now have a cost of $60 to $200/kW in small quantities. This cost should drop to a level of $25/kW or less if higher volume production for electric drivelines is to be competitive with internal combustion drivelines. Although high-performance military traction motors may cost more than $200/kW due to their large speed-torque envelope, the Department of Defense does expect to reduce the differential between commercial and military traction motor costs.

Development efforts to date have focused on AC induction and brushless DC permanent magnet motors. Variable reluctance motors, DC brush-commutated, and homopolar motors should receive more advanced development attention in the FY94 ARPA program. Offerors are invited to consider the specific performance and cost attributes of alternative traction motor technologies. Proposals should be based upon sound projections of performance, efficiency, control complexity, vehicle integration considerations, and cost.

ARPA has an interest in low-voltage (below 50 V) high-current DC homopolar motor designs. The current collection and cooling of such systems may provide some technical risk. Large bus bars required to carry current could have an adverse impact on vehicle weight; however, the following advantages also may exist:

- Low cost
- Improved vehicle safety
- Improved tolerance to battery cell faults
- High-speed torque envelope
- High torque and power densities
- Simplified control (chopping and field control)
- Excellent application for superconducting materials (as temperature increases).

Additional information on existing homopolar motor designs may be obtained by contacting Mr. Howard Stevens, Carderock Division, Naval Surface Warfare Center, Annapolis, MD (301) 293-2857.

Offerors should carefully consider the cost and performance objectives of their proposed efforts as they pertain to specific military and commercial vehicles. When a common motor design meets both military and commercial requirements (e.g., a six-wheel-drive 5-ton truck and a two-wheel-drive transit bus), ARPA will favorably evaluate new motor developments. Motors that have only commercial potential but duplicate the performance attributes of existing motors will not be favorably considered. High-performance motors developed specifically for military vehicles may be favorably considered if such motors can be manufactured from the same flexible manufacturing line that produces commercial motors. All advanced motor developments must show an integrated business approach to meet commercial and military cost constraints.

Power Generation. Hybrid vehicles are likely to be commercially viable in the near future in those pollution-constrained applications where battery-driven electric vehicles do not offer sufficient range or endurance. Existing hybrid designs generally use conventional reciprocating gasoline or diesel fueled engines to drive a permanent magnet generator. Although this combination offers relatively compact volume and modest cost due to the use of existing components with good production volumes, the systems suffer from relatively high part counts, relatively low reliability and high maintenance costs. These attributes negate many of the maintenance cost-reduction attributes of a pure electric vehicle.

The optimum hybrid vehicle power source would have engine and generator functions integrated to offer the fewest parts, the lowest maintenance, and the highest efficiency. One concept that has the potential to meet these objectives is the free-piston linear alternator. High-speed free-piston engine generators have become viable with the availability of permanent magnet materials, improved control mechanisms, and electrically actuated intake and exhaust valves. Because of the potential reduction in overall volume and weight, this concept is also of interest in military applications.

Other integrated engine/generator concepts may also be submitted for consideration such as sliding vane turbines and actively coupled engine/generators. ARPA may support modest cost initiatives that provide insight into the viability of such concepts. Offerors should develop thermodynamic efficiency models, engineering design concepts, and production cost estimates as part of their proposal.

Advanced Drive-Train Components. The viability of electric and hybrid electric vehicles is directly affected by the cost, availability, efficiency, and weight of various drive train components, including electric motors and motor controllers. New drive train technologies that provide cost-effective and efficient alternatives to existing drive train components are sought. For example, the cost of the variable-frequency, 3-phase controller for an AC induction motor driveline may be $250 per kilowatt or more. Alternatives to this high-cost controller are sought. For example, a continuously variable mechanical transmission may be practical when used with a multispeed motor to simplify the motor control and reduce the cost of the electric drive system. In other applications, the use of wheel motors may allow the differential and axle to be eliminated altogether; however, the impact on the suspension system may be substantial and may require novel redesign due to large overhung loads at the motor output shaft. In military applications, the very large speed-torque envelope may be met with high-performance motors or may require use of multispeed final drives. Advanced components are sought to improve the performance, efficiency, and cost of electric and hybrid electric drive.

ARPA is interested in novel technology developments or applications that advance the state-of-the-art driveline technologies. Proposals are not limited to mechanical systems; however, all proposals must demonstrate the potential for superior overall efficiency, weight reduction, cost reduction, and lower part counts.

Energy Management Systems. Energy management systems prioritize and control the use and distribution of energy by vehicle systems. They may be passive, active, or may have both passive and active elements. These systems may include propulsion, HVAC, lighting, thermal management of battery systems, braking systems, power steering systems, and other ancillary power uses (e.g., radios, power windows, windshield wipers). The smart energy management system may include sensors that monitor energy use and prompt the operator to make informed decisions regarding the priority for energy use. In other instances, the energy management system may perform functions of which the operator is not aware.

Experience with existing electric vehicles proves that a well-trained driver can obtain as much as 30 percent greater range per battery charge. This increase in performance is ascribed to a smoother operation of the electric drivetrain with fewer "transient" events. Vehicle operation at a relatively constant power level is more efficient than the intermittent application and subsequent regeneration of power (assuming the same average speed over the same course). Although the operator must have positive control over vehicle speed to operate safely, there are a number of filters and devices that may be used to enhance range performance.

The offeror is encouraged to develop energy management systems that consider combined software and hardware approaches to overall energy management on both hybrid and pure electric vehicles. Offerors should demonstrate an understanding of the relative gains achievable from the control of different aspects of the vehicle. Approaches that have wide applicability and offer substantial reductions in energy consumption will be favored.

Advanced Energy Storage. The Department of Energy is developing high-energy-density battery systems through contracts issued by the U.S. Advanced Battery Consortium. DOE is also funding advanced capacitor development for short-time-constant energy input/output. Efforts that complement but do not duplicate these ongoing DOE efforts will be considered under the FY94 ARPA program.

Figure 3 provides a summary of the current energy and power densities of available and developing energy storage systems. ARPA will consider those efforts that substantially improve the energy and/or power density of specific systems.

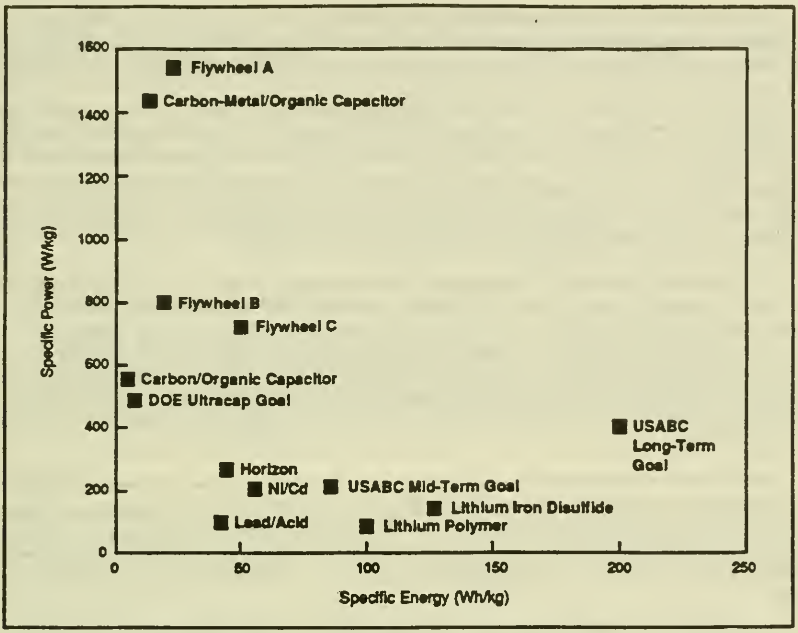

Figure 3. Specific Energy and Specific Power of Energy Storage Devices

The Department of Defense need for tactical and combat vehicles with substantial electric power capabilities led to ARPA's interest in hybrid electric drive at relatively high power levels. The high-power-density components needed for military applications include intermittent energy storage devices, such as flywheels and capacitors, that allow burst power to be delivered for short periods. ARPA is interested in short-time constant-energy storage devices that provide load leveling, reduce system weight, and improve overall energy efficiency. Offerors that have intermittent energy storage devices should relate the performance of these devices to specific performance needs of both military and commercial vehicles. In particular, the ability of the device to operate in a high-motion environment, to fail in a safe manner, to perform reliably, and to operate in environmental extremes should be addressed.

Efficient Battery Charging. The FY93 program has focused on rapid battery charging to alleviate the near-term limitations of electric vehicles operating on conventional lead acid batteries. The ability to recharge battery packs in 12 to 15 minutes while concurrently improving battery life has been demonstrated and this technology is being commercially introduced. Initial indications are that the input/output cycle efficiency of battery charging may also be improved with rapid recharging.

Rapid recharge could increase electrical load on the grid during peak demand hours. Major utilities have argued that the off-peak nature of EV recharging allows better use of existing capacity, while rapid recharging will inevitably lead to a demand for more electrical generating capacity.

The FY94 ARPA program will continue to promote rapid recharging as an element of overall infrastructure development. Concurrently, the FY94 program will seek low-power battery recharging systems that extend battery life, improve battery I/O efficiency, reduce electric infrastructure changes (i.e., reduce cost), and improve the safety of battery use for off-peak charging. Such systems may also be applicable to onboard chargers that operate from a hybrid power source. Offerors should clearly indicate the technology development approach to be followed as well as the battery chemistries for which the approach is likely to be valid.

High-Efficiency Ancillary Components. Many existing electric and hybrid electric vehicles are range limited, in part, by the energy consumption of ancillary components. For example, as much as a third of the electrical load in a shuttle bus operating in an urban environment may be due to air conditioning or resistive heating. Other ancillary loads include power-assisted steering systems, power braking systems, pneumatic or hydraulic door or ramp actuators, lighting, ventilation, etc. The use of ancillary components developed for conventional internal combustion vehicles has resulted in reduced vehicle performance due to the high energy consumption of ancillary components.

ARPA is interested in receiving proposals for specific technology developments that improve the efficiency of ancillary devices or reduce the need for ancillary power in electric and hybrid electric vehicles. Successful offerors will provide new technology and will clearly explore the substantial impact that successful development will have on existing and planned vehicles. Systems may also be proposed that use an alternative source of energy such as photovoltaic or waste heat.

Composite Vehicle Manufacturing. Electric and hybrid electric vehicles in all weight classes benefit from reductions in chassis weight if these reductions do not compromise occupant safety or create significantly higher vehicle purchase cost. A 1-pound savings in chassis weight has a net impact on car weight of between 2 and 3 pounds since the lighter chassis requires a smaller propulsion motor and smaller energy storage. Because of this "multiplier," there are strong performance incentives to reduce chassis weight. The most promising approaches to chassis weight reduction appear to involve unibody sandwich-composite construction. Although aluminum space frame concepts are attractive as a near-term alternative to steel construction, the long-term solutions with greater weight savings potential appear to involve sandwich composite bodies that are manufactured with resin transfer molding, resin injection molding, or other related methods.

The design of a composite vehicle also requires new understanding of the crash dynamics of composite structures. The composite structure may be designed for a wide range of body stiffness and the crash dynamics may vary widely with body stiffness. These aspects of composite body design may be addressed under crash simulation and simulation validation through testing. This composite vehicle manufacturing category is an effort to focus on those manufacturing methods that show clear potential for allowing low-cost manufacture of composite vehicle bodies with moderate-cost materials. These methods must accommodate the need for crashworthiness, point loads imparted by suspension units, vehicle stiffness needed to provide adequate control characteristics, and simple repair methods. Offerors are encouraged to summarize key design constraints for the vehicle of interest that lead to the solution of the proposed composite technology *prior* to proposing the development or application of a specific manufacturing method. Because anticipated production volume may dictate manufacturing method, market assumptions should also be addressed.

Low-Cost Crash Simulation. Automobile manufacturers spend substantial resources to crash-test 100 or more vehicles for each new model introduced. Crash testing has become the method of demonstrating compliance with Federal Motor Vehicle Safety Standards (FMVSS). Large-scale crash testing is warranted by the substantial liability associated with new model introduction; however, the cost of such testing is prohibitive for the small manufacturer. Thus, the cost of proving compliance with FMVSS through crash testing is an obstacle for new manufacturers who may wish to enter commercial competition with low-volume production vehicles.

The availability of high-resolution finite element models is making crash simulation possible. Specialized models, such as Dyna 3D, are being used under Department of Transportation funding by Lawrence Livermore Laboratories and others to predict automotive crash test results. Subsequent crash testing is used to validate the performance of the model. Although such models have been validated for conventional crumple zones in steel automobiles, their performance in predicting the behavior of composite vehicle structures has not yet been fully evaluated.

The existing mainframe finite element crash models, such as Dyna 3D, involve a very large number of mesh points for multiple vehicle elements to offer high fidelity for the many dynamic events that occur during a given crash. Such models may require hours of computation time on the fastest super-computers. Although such efforts may be affordable for a large vehicle manufacturer, or may be justified when a small manufacturer is ready to expand into higher level production, they are not particularly useful for the small manufacturer who is attempting to develop crash-resistant designs.

ARPA is interested in the application or modification of existing low-end finite element codes to meet the needs of small manufacturers or specialty military vehicle manufacturers who would use such models in an iterative manner during the design of electric or hybrid electric vehicles. The proposed application or modification of such models should be contingent upon a strong engineering knowledge of vehicle crash dynamics such that the selection of model simplifications will not invalidate the general prediction. Of particular interest are modeling efforts directed at ultra-stiff and moderately stiff composite structures. Offerors are encouraged to show cooperative work with the Department of Transportation. ARPA will not support efforts that are expressly intended to give one manufacturer a competitive advantage. Results of ARPA-funded efforts should be commercially or publicly available for use by all interested manufacturers.

Crash Test Validation of Simulations. Working in conjunction with the Department of Transportation, ARPA is interested in performing crash tests with new vehicle designs that have been the subject of crash simulations. For example, vehicles designed and built under the FY93 ARPA program or specific test vehicles funded under the FY94 program might be submitted as candidates for crash testing at a DOT facility. The purpose of such tests would be to validate the crash performance simulations that were performed during vehicle design. If crash simulations were not used during vehicle design, the engineering calculations used to determine FMVSS frontal and side impact compliance may be the subject of the validation effort.

The offeror is encouraged to provide a feedback effort to correct deficiencies found in crash simulations (or engineering calculations) that are discovered through crash testing. Unlike the preceding topic, ARPA may, as a by-product of the effort, fund work that will improve the crashworthiness of a specific vendor's vehicle. Although the vendor must agree to make general results available on the correlation between predicted and measured crash performance, ARPA may not require the release of vehicle-specific data.

In developing plans for this specific topic, the offeror is encouraged to contact the following person within the Department of Transportation to propose specific vehicle crash tests at DOT facilities: Ms. Barbara Hennessey, (202) 366-4714.

Occupant Safety Technology in Ultrastiff Vehicles. The reaction of an ultrastiff composite vehicle in a crash will differ from that of a conventional steel vehicle. Conventional steel structure vehicles are designed with crumple zones to absorb some of the kinetic energy of the vehicle in a crash. Ultrastiff vehicles will not absorb as much of the vehicle's kinetic energy in structural deformation. As a result, vehicle occupants may experience larger accelerations in crashes of ultrastiff vehicles. Available restraint systems such as air bags and belt systems may not provide adequate protection for occupants in crashes of ultrastiff vehicles. Innovative occupant protection systems or improvements to existing systems are needed to enhance the safety of ultrastiff vehicles.

Due to their lack of crumple zones, ultrastiff vehicles will have a much shorter crash pulse than conventional vehicles. Safety systems designed for conventional vehicles with longer crash pulses may not be able to operate effectively in short crash pulse conditions. Currently available air bag restraints are designed to activate only when vehicle sensors measure large accelerations that are sustained for a period of time. This is to differentiate between the short-duration accelerations that vehicles experience in normal driving and the large and relatively long-duration accelerations due to crashes. Systems are needed to effectively deploy in short crash pulse impacts yet differentiate between crashes and the accelerations experienced in normal driving.

Another consideration for occupant safety in ultrastiff vehicles is to protect occupants from extreme accelerations in crashes other than in the forward direction. Restraint systems are needed to protect occupants against extreme lateral accelerations such as those that may be experienced by occupants of a vehicle that is hit on the side.

Specialized Military Components. In all other categories of this solicitation, ARPA is seeking dual-use technology advances. Military hybrid electric vehicles will have some components that are not applicable in commercial vehicles. These components may be required to distribute and control power for military systems (e.g., armor, weapons, active suspension, surveillance systems, signature reduction). In addition to normal automotive propulsion and ancillary loads, military vehicles may require the delivery of high-power, moderate-energy pulses for other applications. These intermittent demands may require additional power conditioning, novel storage mechanisms, and specialized power control systems.

ARPA is encouraging the submission of technology development proposals that are pertinent to the requirements for intermittent electrical power for military systems. It is anticipated that there will be some limited commercial requirements for intermittent power. Examples include power to lift devices on electric utility vehicles, power to pumping systems on firefighting vehicles, and power to active nonpropulsion systems on construction machinery.

Other Advanced Technology. ARPA is chartered with the exploration of high-risk, high-payoff technologies that have potential benefit in military systems. Technology breakthroughs are sought in any area that would significantly advance the viability of military and commercial EVs and HEVs. By their nature, these advances may require basic R&D work before their potential can be realized. For example, a new energy storage mechanism could involve the containment of a plasma, the use of a superconductor, new methods of charge transfer between materials, or the extraction of energy from an unconventional source.

Each offeror is encouraged to enter into discussions with universities, R&D organizations, or others who may be working on new concepts for energy storage or extraction. Although ARPA is chartered with high-risk, high-payoff projects, such projects *must* be founded on well-developed theory or experimental results. Unsupported claims of substantial gains in energy storage or conversion performance will not be the basis for ARPA selection. Each offeror is strongly encouraged to seek and include participants who are committed to major breakthroughs in relevant technology based upon basic R&D work.

Mr. KLEIN. Thank you very much, Mr. Worden.

And our final witness is Mr. Michael J. Bradley, the executive director of the Northeast States for Coordinated Air Use Management.

Mr. Bradley.

Mr. BRADLEY. Thank you very much, Mr. Chairman.

What I'd like to do is summarize my comments, but first introduce the concept of what my organization's all about. It represents the eight Northeast State air quality offices from New Jersey, New York, and the six New England States. We attempt to coordinate our responses to air quality problems in terms of technical assessments and policy actions.

In the Northeast, motor vehicles are the largest source of smog-producing emissions, NO_X, and VOCs, as well as the largest source of CO and air toxics. We simply cannot solve our air quality problems in the Northeast without achieving substantial reductions from the motor vehicle fleet.

We're involved in adopting a number of motor vehicle emission-reduction programs, but one of the most promising programs is the one that's been talked about today, the California Low-Emission Vehicle Program, which creates that strong incentive that we've been focusing on to not only develop significantly cleaner conventional-fueled vehicles, but also to produce advanced technologies capable of eliminating tailpipe emissions.

As you are aware, several States in the Northeast have already taken independent action toward the adoption of the California LEV program. Massachusetts and New York have led the way. Each of them began to implement their programs, Massachusetts in this current model year and New York in model year 1996. In fact, California-certified vehicles are now showing up in Massachusetts for sale.

On a regional level, NESCAUM has played a key role in supporting the States, all of the States, to move forward here, working with the Ozone Transport Commission to essentially have the States agree by a vote of 9 to 4 to forward a petition to EPA calling for the implementation of the California LEV program in the entire Ozone Transport Region. That's 12 States and the District of Columbia. The recommendation explicitly addresses the ZEV mandate, asking EPA to make a decision as to whether that's an absolute requirement or if States have the flexibility to achieve similar emission reductions that would be achieved through a mandate through other means.

Based on the information that's been collected to date through EPA's public consideration of the Ozone Transport Commission petition, there does not appear to be any basis for EPA to disapprove the petition. Mr. Beale clearly demonstrated earlier the fact that the Northeast has a severe air quality problem and that substantial reductions above and beyond Clean Air Act measures were going to be required; i.e., the California Low-Emission Vehicle Program along with others.

Consequently, our current assumption is that EPA will approve the petition in its current form. Given this assumption, the potential outcomes related to the ZEV mandate appear to range between, at one end, allowing State-specific determinations on whether to go with the ZEV mandate or not, or at the other, but probably less likely outcome, requiring the mandate in each State.

In New York and Massachusetts alone, the already-adopted requirements related to ZEVs will result in an annual sale of about 100,000 ZEVs in the year 2003. If the ZEV mandate were to cover the entire OTR region, annual ZEV sales would exceed 400,000 cars by the year 2003.

It's important to also point out that nearly every State in the Northeast is not only moving forward with regulatory programs, but also with legislation or regulations to provide economic incentives to support the introduction of electric vehicles and other alternative-fueled vehicles. Both New York and Connecticut, for example, have approved sales and/or income tax credits that would apply to the incremental cost associated with electric or other alternative-fueled vehicles. A wide range of other potential incentives are now under consideration which will simply complement the incentives, the important Federal incentives, that have already been enacted through the Energy Policy Act.

The emphasis on the development and deployment of EVs is warranted, given the numerous benefits which I believe these vehicles will provide. From an air quality standpoint, NESCAUM has found that EVs will offer significant incremental emission reductions beyond those achieved by even the cleanest gasoline-powered vehicles, even taking into account the power plant emissions associated with battery recharging. EVs also further the important policy goal of energy diversification which NESCAUM supports to the extent that it remains consistent with air quality goals.

In the Northeast, the development and deployment of EVs also has the potential to draw upon many of the technological capabilities of the region, and thereby provide an important economic stimulus to the region that has experienced difficulties in recent years as defense-related technology development has received less emphasis. In fact, we are aware of over 100 companies that have chosen to get involved and to make investments in some element of electric vehicle technology just in the last two to three years.

The existence of the EV mandates in California and the Northeast that's created this powerful market stimulus in and of itself resulted in the allocation of significant investment capital for EV-related research and development and, by the way, many advancements. However, in order to further encourage the development of critical technologies, direct financing from the Federal Government has proven to be particularly effective. By emphasizing the role of regional consortia and focusing on projects with the capability to serve both military and commercial purposes, the Defense Department's ARPA program has been very effectively achieving rapid advancements in the development of EV technologies.

For example, in the Northeast alone, in Fiscal Year 1994 the ARPA technology projects included efforts to develop and crash test a purpose-built electric vehicle, develop and demonstrate an advanced energy storage device, and characterize thermal management issues associated with electric vehicles.

I'd like to also suggest that, if you didn't see it, in *The New York Times* yesterday they reported on the development and expected demonstration of United Technology's prototype flywheel that will eventually enable EVs to accelerate more quickly, recapture much more of the energy that is currently lost during braking, perform better at cold temperatures, and achieve longer battery life. This technology, which was viewed two years ago as somewhat of a pipe dream, has quickly advanced to the point where it can be demonstrated in the field and is receiving significant attention from the automakers, in large measure because of the availability and timing of ARPA funding.

In Fiscal Year 1995, it's expected that even a broader range of technologies will be considered for funding. ARPA has, thus, been drawn—able to draw on the related strengths of the regional businesses and universities, and thereby achieve significant gains in a short period of time. NESCAUM strongly supports such partnerships, instead of a more centralized framework which is less likely to result in aggressive and competitive time tables and goals.

In summary, let me say that the ZEV mandate has produced results today. It has pushed the technology. It has shifted investment dollars in a massive way toward development of clean transportation systems. Commitments by State government fleets to dedicated alternative fuels, including electricity, could also help in providing this valuable stimulus that's needed.

NESCAUM recommends that the administration, the Federal administration, follow NESCAUM's lead in the fleet program and require that the Federal Government purchase ILEVs, essentially inherently low-emission vehicles, rather than just converted vehicles. These are the cleaner vehicles that we'd like to see out there in the marketplace.

Federal and State incentives are coming along nicely and will serve an important role over the next five to ten years in assisting the emergence of the electric vehicle market. However, in order to directly stimulate the rapid development of these technologies, NESCAUM would like to express its strong support for the ARPA model, which has been characterized by an emphasis on regional consortia, public-private partnerships, rapid commercialization, and dual applicability. This results-oriented approach appears to offer a high probability of success in promoting the rapid and cost-effective development of electric vehicle technologies, and it's also beginning to put the auto industry in an uncomfortable position when they look around the country and they see small entrepreneurial companies, like James here, producing vehicles that are achieving better and better performance results year after year.

Thank you very much.

[The prepared statement of Mr. Bradley follows:]

NORTHEAST STATES FOR COORDINATED AIR USE MANAGEMENT
(NESCAUM)

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Testimony of Michael J. Bradley, Executive Director
Northeast States for Coordinated Air Use Management (NESCAUM)

before

The U.S. House of Representatives
Committee on Science, Space, and Technology

on

June 30, 1994

regarding

Electric Vehicles and Advanced Battery R&D

Good morning. My name is Michael Bradley and I am the Executive Director of the Northeast States for Coordinated Air Use Management (NESCAUM). NESCAUM is an association of state air pollution control agencies representing Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont. The Association provides member agencies with technical assistance and policy guidance on regional air pollution issues of concern in the Northeast. We appreciate this opportunity to testify before the Committee on issues related to the development and deployment of electric vehicles.

Air pollutant emissions from motor vehicles have, for many years, hindered progress toward attainment of the National Ambient Air Quality Standards (NAAQS) for ozone, carbon monoxide (CO), and other criteria air pollutants. Currently, motor vehicles are responsible for between 30% and 40% of total emissions that lead to the formation of ozone, for which progress toward attainment has been particularly difficult. Motor vehicles also contribute significantly to

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human exposure to air toxics and fine particulate matter, and are the dominant sources of CO in areas that continue to exceed the corresponding NAAQS.

While much progress has been, and will continue to be made in reducing per-mile emission rates of motor vehicles, growth of motor vehicle travel erodes much of the reduction in overall emissions that would otherwise be achieved. Consequently, it is crucial that appropriate incentives be established to ensure that the cleanest possible vehicle technologies are developed and deployed in a timely fashion. In the Northeast, which, outside of California, faces among the most pressing air quality challenges in the nation, significant efforts have been directed toward the development of measures that will stimulate the development of significantly cleaner motor vehicles.

The California Low Emission Vehicle (LEV) program creates an incentive to not only develop significantly cleaner conventionally fueled vehicles, but also to produce advanced technologies capable of eliminating altogether the tailpipe emissions from current motor vehicles -- most likely through the application of either fuel cell or advanced battery technologies. Under the California LEV program, sales of zero emission vehicles, or ZEVs, are required to achieve significant levels over a gradual period starting in the 1998 model year.

Several States in the Northeast have already taken independent initiatives toward adoption of the California LEV program, and Massachusetts and New York plan to begin implementing the program starting with the 1995 and 1996 model years, respectively. On a regional level, the States in the Northeast have joined with the Mid-Atlantic States in petitioning EPA to require that States throughout the Ozone Transport Region (OTR) include the California LEV program as a key element of an approved State Implementation Plan (SIP). The petition retains the ZEV mandate as an optional element to be adopted on a State-by-State basis in the event that EPA determines it is not a required component of the LEV program, and as a required element in the event that EPA does not make such a determination. In any event, the petition would require that the same overall emission reductions be achieved as from a motor vehicle fleet that includes the mandated level ZEVs.

Based on information that has been collected to date through EPA's public consideration of the Ozone Trasport Commission (OTC) petition, there does not appear to be any basis for EPA to disapprove the petition. Consequently, our current assumption is that EPA will approve the petition in its current form. Given this assumption, the potential outcomes related to the ZEV mandate appear to range between, at one end, allowing State-specific determinations and, at the other, requiring the mandate in each State. In New York and Massachusetts alone, the already-adopted requirements related to ZEVs will result in the annual sale of over 100,000 ZEVs by 2003. If the ZEV mandate is required throughout the OTR, it is projected that annual ZEV sales will exceed 400,000 by 2003.

The air quality agencies in the NESCAUM region are also actively pursuing complementary measures to encourage electric vehicles and other alternatively fueled vehicles (AFVs). Most of the States in the region have obligations under the 1992 Energy Policy Act (EPAct) to begin the conversion of fleet vehicles toward alternatives to petroleum-based fuels, including electricity. NESCAUM members have mutually agreed to jointly pursue an initiative through which State government fleets in the region would comply with EPAct obligations by purchasing Inherently Low-Emitting Vehicles (ILEVs). Through dedicated operation on alternative fuel, ILEVs would achieve not only very low tailpipe emissions, but also near-zero evaporative emissions. Although EPAct requirements allow dual-fuel operation, a commitment to dedicated alternatively fueled vehicles would allow State governments to both demonstrate leadership and further stimulate the early market for AFVs.

Nearly every State in the Northeast also has legislation either approved or in development that would create incentives for the development and sale of EVs and/or other alternatively fueled vehicles. Both New York and Connecticut, for example, have approved sales and/or income tax credits that would apply to the incremental costs associated with electric and other alternatively fueled vehicles. A wide range of other potential incentives are under consideration, examples of which include:

- reduced electricity rates for EV operators
- financial and regulatory incentives for EV manufacturing
- incentives for EV refueling infrastructure development
- exemptions from parking restrictions
- exemptions from inspection/maintenance requirements
- exemptions from tolls
- exemptions from high-occupancy vehicle (HOV) lane restrictions

Such incentives complement the important Federal incentives that are already provided under EPAct, which include financial assistance for selected infrastructure projects, low interest loans for EV purchasers, and also the 10% Federal income tax credit for incremental costs associated with EV purchases.

This emphasis on the development and deployment of EVs is warranted given the numerous benefits these vehicles will provide. From an air quality standpoint, NESCAUM has found that EVs will offer significant incremental emission reductions beyond those achieved by even the cleanest gasoline-powered vehicles, even taking into account the power plant emissions associated with battery recharging. EVs also further the important policy goal of energy diversification, which NESCAUM supports to the extent that it remains consistent with air quality goals. In the Northeast, the development and deployment of EVs also has the potential to draw upon many of the technological capabilities of the region, and to thereby provide an important economic stimulus to a region that has experienced difficulties in recent years as defense-related technology development has received less emphasis.

Despite these advantages associated with EVs, both in California and in the Northeast, the ZEV component of the LEV program has been met with considerable opposition by the major auto makers. Arguments against the mandating the sale of ZEVs have been based, to a great extent, on the following elements: recharging-related emissions, technological feasibility (i.e., performance), and cost. As discussed above, NESCAUM has found that future recharging-related emissions will be significantly lower than gasoline-powered vehicle emissions. While significant technological challenges clearly remain, mostly importantly in the area of energy storage, the performance of even currently available conversion EVs is already sufficient to meet the needs of many commuters in the region. Although currently marketed EVs are, indeed, more expensive than their conventionally fueled counterparts, it should be noted that economies of scale have yet to be realized, and that nearly all EVs currently available for purchase are conversions of conventionally fueled vehicles rather than EVs designed and built from the ground up -- which means that significant opportunities to improve performance and reduce cost are currently missed. Over the next two to five years, we expect to see significant performance improvements and cost reductions as technological and manufacturing advances are achieved through efforts already showing results.

The existence of EV mandates in California and in the Northeast has created a powerful market stimulus that has, in and of itself, resulted in the allocation of significant investment capital for EV-related R&D. However, in order to further encourage the development of critical technologies, direct financing by the Federal government has proven to be particularly effective. By emphasizing the role of regional consortia and focusing on projects with a demonstrable capability to serve both military and commercial purposes, the Defense Department's Advanced Research Projects Agency (ARPA) has been able to very effectively achieve rapid advances in the development of key EV technologies and manufacturing techniques. For example, in the Northeast alone, fiscal year 1994 ARPA technology projects included efforts to develop and crash test a purpose-built electric vehicle, develop and demonstrate an advanced energy storage device, and characterize thermal management issues associated with electric vehicles. In fiscal year 1995, it is expected that an even broader range of key technologies will be considered for funding.

ARPA has thus been able to draw on the related strengths of regional businesses and universities, and thereby achieve significant gains in very short periods of time. NESCAUM strongly supports such partnerships instead of a more centralized framework, which is less likely to result in aggressive and competitive timetables and goals. NESCAUM also strongly supports the dual-use emphasis that has been adopted by ARPA, which not only ensures that researchers pursue technologies whose costs are consistent with commercial requirements, but also makes it easier for the military to enjoy the lower costs typical of the commercial sector.

In NESCAUM's view, State-level adoption of ZEV mandates provide the strongest incentive to rapidly develop appropriate EV technology. Commitments by State government fleets to dedicated alternative fueled vehicles, including electricity, could also provide a valuable stimulus -- one that could be significantly augmented through similar commitments by the Federal government. NESCAUM recommends that the Administration strongly consider requiring that AFVs purchased under EPAct meet ILEV emission standards or that, at a minimum, Federal fleets meet EPAct obligations through the purchase of ILEVs. Federal and State incentives for EV purchase and use will also be important, particularly in the first few years when EVs are marketed. However, in order to directly stimulate the rapid development of key technologies, NESCAUM recommends that the Federal government rely on the ARPA model, which is characterized by an emphasis on regional consortia, public/private partnerships, rapid commercialization, and dual applicability. This strongly results-oriented approach appears to offer a high probability of success in promoting the rapid and cost-effective development of EV technologies.

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To: Interested Parties
From: Michael Bradley
Date: March 21, 1994
RE: EPA Draft Report on Electric Vehicles

I am writing to bring to your attention a draft report on electric vehicles that EPA plans to release in the near future. We have reviewed a copy of this report, and have identified numerous aspects of the analysis that lead to a very significant understatement of the benefits of electric vehicles. The results of this preliminary study first surfaced in January 1994 in advance of the February 1, 1994 Ozone Transport Commission (OTC) meeting where regional adoption of the Low Emission Vehicle (LEV) program was under consideration. In light of the attention that this report has already received by the press, and the likely coverage that will follow its release, I'd like to take this opportunity to point out in advance some of the shortcomings that we have found.

The report in question is the draft of a preliminary assessment of electric vehicles which was prepared in November of 1993 by staff of EPA's Office of Mobile Sources (OMS) for review by senior management within OMS. It was not subjected to peer review either within EPA or outside of the Agency. Nonetheless, citations recently began to appear in numerous places that identified this report as evidence of the impracticality of electric vehicles. However, OMS has steadfastly denied all subsequent requests by NESCAUM and others for copies of the report.

In reviewing a copy of the report, it is clear that OMS has failed to seek technical advice from many of the key experts in the electric vehicle field. Given this lack of outside input from a range of interested parties, it is in some ways unsurprising that the report appears to suffer from several serious technical flaws. It is, however, astonishing, especially given the status of the OTC LEV petition, that this report would be cited in the press, and that it would be held so tightly thereafter.

A technical review of this draft study is attached. Thus far, we have identified three key areas in which the assumptions made by OMS are clearly biased against electric vehicles:

1. OMS has overestimated vehicle energy consumption by 50%-130%, relying upon a computer model that has never been reviewed outside of the agency, rather than on actual measurements of existing vehicles.

2. OMS has overstated NOx emission rates for electrical generation, relying on nationwide average emissions in 1992. Taking into account geographic differences in electrical generation, and reductions that will be achieved in response to Title I of the Clean Air Act, we find that OMS has overstated utility NOx by about 300%.

3. OMS understates the benefits of electric vehicles by relying on baseline scenarios for internal combustion engine (ICE) vehicles that include inspection/maintenance and

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reformulated gasoline programs that will not be needed for electric vehicles. As a result, OMS has understated the benefits for electric vehicles by a factor of two for VOC.

As a result of these biases in assumptions and methodology, OMS significantly understates the benefits of electric vehicles, and the resulting cost-effectiveness of electric vehicles as a technology to reduce air pollution. While this is unfortunate, it is not nearly as problematic as the process from which it resulted, which was characterized by a profound lack of involvement by outside interests.

I encourage you to closely examine OMS's report, and to comment in the appropriate manner. If there is anything NESCAUM can do to assist you, please contact either Kevin Greer or me at (617)-367-8540.

attachment

Distribution List:

MARAMA Directors
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NESCAUM Mobile Source Committee
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P. Billings, ALA
M. Walsh, Consultant
S. Lynch, NAVC

Emissions from ZEV Recharging
Comparison of EPA (11/93 Draft) and NESCAUM Studies

Background

In July of 1992, NESCAUM funded a study of emissions associated with electrical generation that would result from the charging of electric vehicles marketed in the northeast under the California LEV program.[1] Due to the complexity of the task, prior studies had neglected utility emissions associated with ZEVs. Given the importance of the ZEV sales mandate, and the range of stated opinion regarding its applicability to the northeast, it was clearly important that decision makers in the northeast be provided with the best possible assessment of its air quality implications. It was in this spirit that NESCAUM commissioned this study, whose major tasks involved (i) defining the size and average efficiency of the future EV fleet in the northeast, (ii) characterizing the future marginal generating mix for Northeast power pools, (iii) estimating pollutant emission rates from future marginal generating units considering the implementation of the 1990 Amendments to the Clean Air Act, and (iv) estimating utility emissions associated with EV charging. Draft and final versions of this report were distributed widely to for comment by interested parties, including EPA.

In November of 1993, a preliminary draft report addressing the costs, energy, and environmental implications of EVs was prepared by EPA staff for discussion with senior managers.[2] The report had not been peer reviewed and as a result, it was not distributed outside of the Agency. However, early in 1994, several press articles appeared that took note of this report, citing it as a source of pessimism regarding EVs. Despite these citations, the Agency has declined requests by NESCAUM and others to make the report available for review and comment.

NESCAUM staff recently obtained a copy of EPA's draft report, and have identified several key areas where the approaches, assumptions, and estimates relied upon by EPA differ widely from those included in the NESCAUM report:

- EPA estimates of EV energy consumption are based on the use of a computer model that has not been subjected to a peer review process. The NESCAUM report relies upon manufacturer energy consumption figures for actual limited-production and prototype EVs. As a result, **the vehicle energy consumption estimates used by EPA are 50%-130% greater than those used by NESCAUM for similar EVs.**

- EPA estimates of utility emissions are based on the nationwide average emissions from power plants in 1992. NESCAUM's analysis is based on projected future emissions of power plants in the Northeast, and takes into account the significant emission reductions that will be achieved in the region in response to the 1990 Amendments to the Clean Air Act. **For NOx, EPA's estimates of utility emission rates are thus a factor of four greater than those used by NESCAUM.**

- In calculating the benefits of EVs, EPA refers to a number of different scenarios regarding baseline vehicle emissions. However, each of these baseline vehicle scenarios assume the presence of volatility controls, gasoline reformulation, and inspection/maintenance and anti-tampering programs. Given that none of these programs are required for EVs, it is suggested here that the proper baseline for determining EV benefits assume they are not present. **Preliminary calculations by NESCAUM staff indicate that EPA has thus understated the baseline for VOC, for example, by at least a factor of two.**

These issues, and their implications regarding the assessment of EVs, are discussed at greater length below.

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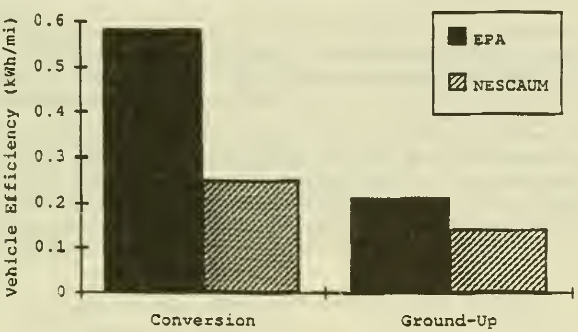
[1] Tennis, M.W., *Impact of Battery-Powered Electric Vehicles on Air Quality in the Northeast States*. July 1992.

[2] U.S. EPA - Office of Mobile Sources. *Preliminary Electric Vehicle Assessment (Draft)*. November 3, 1993.

1. Vehicle Energy Consumption

EPA has estimated EV efficiency using the several vehicle parameters (e.g., drag coefficient, vehicle weight, rolling resistance, etc.) as inputs to a computer model that calculates vehicular energy demand. EPA performed such calculations using assumed characteristics for several classes of EVs: Pb-A and Na-S conversions and Pb-A and Na-S ground-up vehicles (GM Impact type). The 1992 NESCAUM study relied on manufacturer-provided measurements of vehicle energy consumption for actual lead-acid conversion (Solectria Force) and ground-up (GM Impact) vehicles.[3] These estimates are compared in the following chart to those calculated by EPA[4]:

Estimated Efficiency of Lead-Acid EVs



As is indicated, the Pb-A conversion passenger vehicles examined by EPA are assumed to consume more than twice as much energy as a Solectria Force, and nearly three times as much energy as the average Pb-A passenger vehicle modeled by NESCAUM in 1992. EPA also estimates 50% greater energy consumption for a Pb-A Impact than the NESCAUM study. Although EPA provides gram/mile emission estimates for Pb-A and Na-S Impact-type vehicles, it has limited cost-effectiveness estimates to conversion vehicles.

2. Utility Emissions

EPA estimates emissions based on nationwide average emissions from electric power plants in 1992, and thus fails to take into account the significant future emission reductions in the Northeast and elsewhere that will result from the 1990 Amendments to the Clean Air Act. The NESCAUM study relies upon an analysis of the future on-the-margin fuel mix and resulting average emission rates for power pools in the northeast, taking into account the significant reductions (particularly in NOx) that will result from implementation of the 1990 CAAA. The differences between these two approaches are illustrated in the following table.

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[3] Assuming a mix of conversion and ground-up vehicles, NESCAUM's report projects a near-term fleet-average efficiency of 0.20 kWh/mi. A range of 0.17-0.22 kWh/mi is examined in a sensitivity analysis.

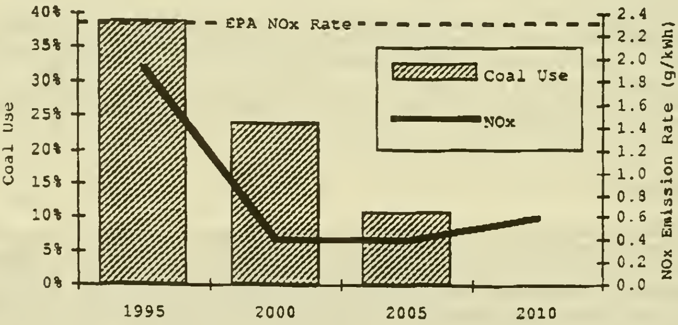
[4] EPA's reported values for "vehicle efficiency" have been adjusted upward by 15% (EPA's estimate of charging loss) in this chart to make them comparable to NESCAUM's estimates, which include charging losses.

	Electrical Generation Mix				NOx Emissions (g/kWh)		
	EPA (1992)		NESCAUM		EPA	NESCAUM	
Fuel	Nat'l	NE Avg.	1995	2010	Nat'l	1995	2010
Coal	56%	35%	39%	0%	3.8		
Oil	3%	18%	23%	49%	2.4		
Nat. Gas	9%	7%	36%	46%	1.1		
Other	31%	39%	2%	5%	0.0		
Composite					2.3	1.9	0.6

Although they are not used in estimating EV emissions, EPA does provide comparative average fuel mixes in the northeast and California. In the northeast, EPA's estimates indicate an average mix of 35% coal, 18% oil, and 7% natural gas.

In contrast, the 1992 NESCAUM report takes into account the fact that EV charging will represent an incremental load above and beyond the aggregate nonvehicular electrical demand. Therefore, rather than relying on the projected future average fuel mix, which includes significant amounts of coal (16% in 2010), nuclear (12%), and hydroelectric (14%) generation, NESCAUM has relied on the projected marginal fuel mix, which is expected to be dominated by oil and natural gas in the future. For 1995, such an analysis yielded an on-the-margin NOx emission rate of 1.9 g/kW-hr, assuming a mix that included 39% coal. However, NESCAUM's report projects significant shifts away from on-the-margin coal use, and other improvements in stationary source NOx control. Taken together, these changes result in an eventual NOx emission rate of 0.6 g/kW-hr, which is nearly 75% lower than the emission rate used in EPA's analysis. This shift is illustrated in the chart below, which also indicates the 2.3 g/kWh NOx emission rate used by EPA to estimate EV charging emissions:

On-the-Margin Coal Use, NOx Emissions



These projections of future on-the-margin coal use and NOx emission rates are based on New York State Energy Office (NYSEO) estimates of future trends, which take into account the expected impacts of Title I requirements for fossil-fueled generation. This is directionally consistent with the commitment by NESCAUM member agencies to pursuing Phase II NOx control for utility boilers.

3. Baseline for Comparison

In estimating cost-effectiveness of conversion passenger EVs (lead-acid and sodium-sulfur), EPA compares EV emissions to several different base vehicles, for which it estimates the following emission rates:

Vehicle	I/M Type	NOx g/mi	VOC g/mi
Tier I	Enhanced	1.18	0.956
CA LEV	Enhanced	1.06	0.566
ILEV	Enhanced	0.73	0.430
CA LEV	Maximum	0.48	0.216
ILEV	Maximum	0.25	0.080
Pb-A Conversion (EPA)		1.49	0.012
Na-S Conversion (EPA)		0.88	0.007
Average Pb-A EV (NESCAUM)		0.12	0.003

As mentioned above, EPA's emission rates for EVs are based upon vehicle energy consumption estimates that are significantly higher than used by NESCAUM, and upon utility emission rates that are also significantly greater than projected by NESCAUM for the northeast. **Taken together, these differences result in more than a ten-fold difference in estimated NOx emission rates.**

However, in light of the fact that the following programs are not required for EVs, it is here suggested that a true baseline for comparison be developed assuming they are not present: inspection/maintenance, antitampering, volatility control, and gasoline reformulation. The suggested ICE (internal combustion engine) baseline thus relies on full useful life emissions of Tier I vehicles (with on-board vapor recovery) without these programs. This yields a slightly higher NOx baseline and a **doubled** VOC baseline:

	NOx g/mi	VOC g/mi
Suggested ICE Baseline	1.28	2.000
NESCAUM Avg. Passenger EV	0.12	0.003
EV Benefit	1.16	1.997

Further upward adjustments to the ICE baseline would also be appropriate in light of recent findings related to shortcomings of the Federal Test Procedure (FTP). Relative to the FTP, EPA has found that actual driving patterns exhibit increased throttle variability, higher speeds and accelerations, shorter trips, and more frequent intermediate duration vehicle soaks (engine-off time between trips) - all of which are expected to result in increase emissions from ICE vehicles.

In fact, this approach toward baseline determination could conceivably be carried somewhat further, as selective enforcement auditing, emissions recall, and emissions warranty requirements would not be needed for EVs.

Conclusion

EPA's draft analysis exhibits several serious potential biases in approach and estimation that result in significantly greater calculated levels of emissions associated with EV recharging than found in the report prepared for NESCAUM in 1992. First, EPA's use of a modeling-based approach to the estimation of vehicle energy demand yielded values 50%-130% higher than expected based on manufacturer date provided to NESCAUM in 1992. Second, EPA's reliance on nationwide average utility emissions for 1992 seriously overestimates future utility emissions, particularly in the Northeast, where significant reductions will be achieved in response to the 1990 CAAA. Third, EPA's relies upon ICE baselines for comparison which fail to take into account the fact that several key programs will not be needed for EVs, and as a result significantly further understates the emission benefits of EVs. An analysis of EV emissions consistent with NESCAUM's approach, coupled with fair baseline for comparison, would indicate that EVs are significantly more cost-effective than shown by EPA.

Mr. KLEIN. Well, thank you very much, Mr. Bradley. And I want to thank the entire panel for extremely informative and thought-provoking testimony.

Mr. Williams, the Advanced Battery Consortium's original time table called for pilot-scale production of an advanced mid-term battery by 1994, did it not?

Mr. WILLIAMS. That's correct.

Mr. KLEIN. Now DOE is talking about pilot plant production of a mid-term battery in Fiscal Year 1996 or 1997, which could mean as late as calendar year 1998. And your testimony refers to a target date no earlier than 1999. How do you account for this apparent slippage?

Mr. WILLIAMS. The original goals were very aggressive, and I think they should be. We had some trouble getting started. I think some of that was to set the framework for how we would work together to put the original contracts in place. I'd characterize them as administrative and bureaucratic problems. So we started up more slowly than we anticipated.

But I think we're making good progress and those mid-term goals are in sight. I'd like it to happen more quickly. Different people have different projections of the future, but that's our current projection, based on everything we've accomplished so far and what we know now.

Mr. KLEIN. Well, you know, with a five-year slippage, to say that's making good progress—it's hard to say that that makes for good progress. Let me ask you another question.

Mr. WILLIAMS. Sure.

Mr. KLEIN. You have indicated that the Battery Consortium is a $260 million program cost-shared between Detroit and the Federal Government. What is the total funding that GM and the other U.S. automakers are putting into advanced battery and electric vehicle technology development at this point?

Mr. WILLIAMS. I'm not sure I can speak to all electric vehicle development. I could speak to the battery portion of that.

Mr. KLEIN. Fine. Do it that way.

Mr. WILLIAMS. Because the battery portion—of the $260 million, approximately $60 million of that is from the car industry.

Mr. KLEIN. Okay, that's $60 million from the car industry. At a hearing in this committee on another subject a couple of weeks ago, I heard testimony that the auto manufacturers spend about 10 percent of the total cost of a vehicle on design. It would seem to me, if those figures are correct, that $60 million represents an absolutely minute fraction of what the automakers are spending on design. Why shouldn't we be spending a great deal more? Why should not the automakers be spending a great deal more on the design and development of either electric battery vehicles or some other form of vehicle that will achieve the goals that this Nation very clearly needs to attain?

Mr. WILLIAMS. I think I can speak for all three automakers in our Consortium, that they're spending significant amounts of money. Our demonstration program——

Mr. KLEIN. Well, when you say, "significant amounts of money," $60 million for all three automakers does not sound like significant amounts of money.

Mr. WILLIAMS. I think it's significant. You know, General Motors alone, before the Consortium, might have spent a few million a year on battery development. You know, we're up significantly on that. Plus, in cooperating with other people, you know, we've put together, half industry, half government, we've put together a quarter of a billion dollars. That's a good effort, and I think we're getting there by cooperating, industry and government, GM, Ford, and Chrysler. As opposed to fragmented efforts, it's a very focused effort.

Mr. KLEIN. Well, Mr. Worden says that the California 1998 EV requirement is feasible. His firm has 35 employees now, but says that the EV industry may be like the computer industry, where small firms like Apple or Microsoft grow into big ones. Now maybe our future lies with small companies like that, that are creative, that are innovative, that are aggressive, and maybe the Big Three automakers are, for whatever reason, are just not in tune to what America needs today in this area.

Mr. WILLIAMS. I think, you know, James makes a good point that we all have a role to play in moving EVs forward. We certainly are committed from the car company side. I personally am committed. I'm an EV enthusiast. I had one of our demo cars home over the weekend, and it's the neatest car I've ever driven. You know, there's no question that we're very committed from our side, and everyone has a role to play. I accept that as legitimate.

Some things, to really do a program, to really put lots of cars out there that will really satisfy real customers, takes the capability and inertia of a large company. These cars have to be absolutely safe, absolutely durable. They have to satisfy our customers on a regular basis, and there's some things that small companies can do best and there's some things that large companies can do best.

Mr. KLEIN. Well, you know, it's very interesting that you use the word "inertia" because my limited knowledge of school physics indicates that inertia works both ways.

Mr. WILLIAMS. Sure.

Mr. KLEIN. It tends to—those things that are moving tend to keep on moving and those things that are at rest tend to stay at rest, and the question is: is the inertia in the Big Three automakers one of movement or one of stagnation?

Mr. WILLIAMS. I certainly agree with your observation on inertia. I could speak for my company, General Motors. We've had EV programs every 10 years as long as I know. I personally have worked on our electric vehicle program since January of 1990, and there is more capability there and more moving inertia and more commitment to EVs than any other place that I know

Mr. KLEIN. Mr. Ovshinsky, your very provocative comments suggested that we look beyond just electric batteries and electric vehicles, but we've got a broader quest. Where do you see us going in terms of achieving what I see as the necessarily achievable goal, and that is that we've got to—as a nation, we've got to solve this problem of providing private automobiles that are not dependent upon foreign oil, that are inexpensive and at the same time are clean vehicles and stop the auto emission problem that is clearly a tremendous problem for our Nation?

Mr. OVSHINSKY. Well, I'm glad that you ask that kind of question because I think that one of the things that we need to put into historical perspective is that this is not a clash of either personalities or even of ideas. For example, Mr. Williams has dedicated a very important part of his working life—and I know that for a fact—to making electric vehicles practical, and he would be the last person to try to defend or stop progress.

What we face here is a different kind of a problem. What we face is that there is a—I hate to use the term—paradigm shift that's occurring with huge industries, the largest industries really in the world having to turn around and make change, and this isn't a matter of maliciousness. It isn't a matter of conspiracy. It's a matter of that is what is—the fact is that there is change now taking place in the automotive industry. It isn't taking place fast enough as I would like it.

So what do we do about that? The problem I don't believe is technological. I just must say that. The problem is sociological. We have to be understanding, and we have to put in place the mechanism, and that's where government, I think, plays such a key role, to have this transition take place with groups that are really not accustomed to that kind of a change, but who are dedicated to serving the public.

The way I feel that one can remove it from the legal battle of mandates is to build cars, electric cars, get them out there, get the process started. Once you do that, market forces take over. If anyone studies the history—and I go back to a broader perspective—the history of copiers, the history of portable phones, the history of fax machines, you name it, the projections are not the—the marketing projections were not the important things. What was important is they got out there, showed what they could do, and won on their own merits. And I believe that that's what the electric car can achieve, given the opportunity.

I believe that it is part of the Consortium's job—and just to think of Ford, Chrysler, and General Motors working together, as they did and are doing with the Department of Energy and the utilities, I mean, the slowness may be something that we all feel bad about. I know that I am very upset with it at times, but one has to understand that that's an incredible achievement in itself and that they're working together is what's important.

However, I do believe—I do believe—that the only way that this is going to happen is by the use of production, and for production we need investment, and the investment we need is to lower the cost. That could come from the funding agencies that have been represented here at this table previously.

Mr. KLEIN. Well, Mr. Ovshinsky, I must say I agree with much of what you said. If, as you state—and I happen to agree—the problem is not technological but sociological, then how do we overcome that sociological barrier? Sure, we want to—if you produce the prototype vehicle and you get it out into the marketplace, yes, I think that's right; that's going to attract people. It's going to get people to buy vehicles like that. But we first have to get to the point of producing that vehicle that is out in the marketplace.

Do you think that GM should have to take until 1999 to start producing this advanced battery vehicle now that they have a joint venture? Isn't there some way in which we can move, overcome that sociological barrier and move up that date, so that we can get it out into the marketplace? And whether it's GM or the Big Three automakers or Mr. Worden's company or some other company that we haven't yet heard of that will make the breakthrough——

Mr. OVSHINSKY. Well, first of all, I——

Mr. KLEIN [continuing]. What do we have to do to attain this?

Mr. OVSHINSKY. I think what you're doing. I can't speak for General Motors. I can't really speak for GM-Ovonic, which is a joint company with my company and General Motors. All I can say, it is not our plan to take until 1999. This is not what I believe is going to happen. This cannot be allowed to happen, and it is my personal commitment to make sure that it doesn't happen.

And so I feel that you're seeing things happening as they do in real life, not in a very orderly fashion, but things are coming together. The important thing is that there is a GM-Ovonic. I never would have thought that was possible, if I was called several years earlier here. The largest corporation in the world, larger than some countries, the flagship of United States industry—I believe that that's a tremendously good sign of a huge company turning itself around and adjusting and becoming a leader—a leader.

They have a car called the Impact, and I don't want to make light of James' kind of work because it is really—he represents the future of American industry, but the Impact is a beautiful car. I can't speak for GM's plans. I cannot speak for the plans of a company that's just being formed—GM-Ovonic—but I can tell you that it will not be in that kind of time frame. And those who try to put it into that kind of time frame I think will come around.

It is not up to us to make enemies. It is up to us to win over people, and I believe that confrontational politics at this point is not what's needed. What's needed is continued pressure on the Consortium to speed itself up.

We talked about a plant. I've worked for over a year trying to get a plant policy going in the Consortium and failed, but I don't think I truly failed; I think that there are things now that are happening. I worked for over a year to try to get funds that would allow me to go beyond the mid-term goals because I speeded up the mid-term specifications. We had a three-year contract. Within a year and a half, we put batteries into cars because we believe that that's the way to do it, not just follow a structured process: "you do this; you do this; you do this," but what can you really do to solve a tremendous problem for all of us and for the governmental interest?

And I believe that these things will happen. They're not going to be easy. They're—not because, however, there isn't technological progress. There's going to have to be changes of mind. There has to be people who change the way they look upon an automobile, because when I grew up gasoline was in our veins, we used to say, and now that means that there's also vapor in the brain. So we have to do something about that. [Laughter.]

Mr. KLEIN. Well, I didn't—certainly it was not my desire to be confrontational, but rather to prod an industry that I think there are times when a little bit of prodding and goading and pushing achieves a great deal. I think maybe if we had prodded the Big

Three automakers 15 years ago, it would have been better for the auto industry, although—what happened in that 15-year period, how Japanese automakers and other European—other overseas automakers stole a great share of the U.S. auto market. So when we prod, we're not being confrontational; we're not being against the auto industry. We're being in favor of the auto industry, but I'm suggesting that there are both environmental, sociological, and market forces that I think are urgently saying we've got to move ahead more rapidly than we are.

Mr. OVSHINSKY. Can I just say one thing?

Mr. KLEIN. Sure.

Mr. OVSHINSKY. I will be your prodder. I guarantee you that. But I will do it in a way that allows us to get it done, not by breaking alliances, but by building alliances, by building, enlarging the circle, by working together as a team effort, as was explained by Mr. Williams. Because to just be against it is not going to help us.

I am committed, my company is committed, our people are committed to making sure that the tools are in place. We are a resource for the automotive industry and we intend to be used.

Thank you.

Mr. KLEIN. Well, thank you.

I do want to give Mr. Ehlers an opportunity. I know he's got some very good questions. But before I do, I just want to ask one question or actually two questions, but they're really very much related, and they were suggested by Ms. Harman earlier in her opening statement.

A June 22nd article in *The Wall Street Journal* stated that the two largest California utilities will begin fleet evaluations of Honda Civic electric vehicles starting this summer, and I would ask all of you, are you aware of any other Japanese car makers' plans to introduce electric vehicles in the United States? And what can you tell us generally about Japanese battery technology and the cost-competitiveness of their electric vehicles? Is Detroit falling behind in the EV competition, the way it did with fuel-economical cars in the late 1970s?

Mr. WILLIAMS. I'd be glad to speak to that. I think the Honda program that's referenced there is a demonstration program like the Ford Ecostar program that's some eight months old and the General Motors Preview program that was introduced last Thursday. And what Honda is doing there is a strategy of building confidence steadily. Before going into production in some volume into a market that's very uncertain with a product that's not thoroughly developed, they're going to have a very small demonstration fleet and try it out.

Our friends at the DOE have sponsored demonstration programs. GM, Ford, and Chrysler all have demonstration programs, and I think that's a very valid strategy of starting small, building confidence steadily, because the worst thing that can happen is if we make decisions too quickly and have an incident or a setback of some sort that has a backlash on the whole movement. That ultimately hurts what we all want to do. So I think a demonstration program is good. I think that's what Honda is doing.

The Japanese Ministry of Industry and Trade is investing very, very heavily in long-term batteries. They're investing more money sooner in long-term batteries than we are. We don't have any reason to believe they're ahead of us now, but that's all very uncertain. That's looking for a breakthrough. There's no question there's competition there.

Mr. KLEIN. Any other members of the panel want to comment on that subject?

Mr. BRADLEY. Sure. Just following the trade press, it's very clear that all of the auto companies in Japan have very aggressive, fairly large EV development programs, and under MITI there's a lot of coordinated support from the Federal Government in Japan.

I believe they have a production goal of a million vehicles in the year 2000 as a goal for——

Mr. KLEIN. That's ahead of us, if they were to attain their goal?

Mr. BRADLEY. I haven't heard of a U.S. production goal, but I would imagine it certainly would exceed a goal that——

Mr. KLEIN. Well, I was referring to the—Mr.—the comment by Mr. Beale of the EPA. The production figures that he was citing are significantly behind the one million goal that you mention of the Japanese.

Mr. BRADLEY. Sure. Sure.

Mr. KLEIN. Mr. Worden, do you have anything to add to that?

Mr. WORDEN. No, we don't have much interaction with the Japanese automakers, but we definitely know that, from the press again, there is——

Mr. KLEIN. Yes.

Mr. WORDEN [continuing]. A great deal of activity over there and a lot of money going into these vehicles.

Mr. KLEIN. Right.

Mr. OVSHINSKY. Well, I have contact with the Japanese automotive manufacturers and I can tell you that they're very, very serious about the electric vehicle, very serious about the battery, and I wanted to assure the panel here that we will do everything that's necessary to defend our proprietary interest. We have the basic patents in nickel metal hydride batteries and we intend to make sure that they are respected over the world and, of course, in Japan as well.

Anything that we do will benefit the Consortium because we have always given the American industry the advantage.

Mr. KLEIN. Thank you.

Mr.—my friend, Mr. Ehlers from Michigan.

Mr. EHLERS. Thank you, Mr. Chairman. In view of the hour, I will try to be brief.

A few comments: first, I do want to follow up on your comment about prodding and say that it's always good to prod a bureaucracy. I think our Federal bureaucracy gets prodded by our constituents who prod us and we prod the bureaucracy. And so I make no apologies for prodding the Big Three or any other bureaucracy. In my experience—part of it is, of course, I'm from Michigan and so the auto industry is an industry we love to hate. There's a unique love-hate relationship between the State of Michigan government and the auto industry. But I often marvel that the bureaucracy and the Big Three was certainly the match of anything I encountered in State government. You have a little ways to go to match the Federal Government, though. [Laughter.]

Just a few questions—oh, one other general comment before I get to my questions. Throughout this there's been sort of the assumption that the zero-emission vehicles are going to be a great boon, and I think we have to be a little careful in that I'm sure the experts here—and I want to make sure everyone recognizes that still the energy comes at an environmental cost because you have a power plant producing it. You've displaced it. It's somewhat less because electrical devices are so extremely efficient, and so you have a higher efficiency, but you're still limited by power plant efficiency and power plant emissions, and we can't lose sight of that.

I think probably the best advantage of the ZEV is for commuting, and particularly in heavy traffic. The biggest advantage, of course, they are truly zero-emissions vehicles when they're standing still, which is not true of an internal combustion engine. And that's a big factor in today's gridlocked society.

But a couple of specific questions: Mr. Worden, I would be interested in your opinion of the hybrid vehicle. Are you thinking at all of getting into that? Do you see that as playing a role in this, or do you think we're better just going with the type of vehicle you produce?

Mr. WORDEN. We believe, again, that the electric vehicle can meet the needs of most commuter and fleet purposes. The hybrid vehicle, of course, with much longer range, but the complexity of the hybrid vehicle and the development to get a very small engine to be clean is not a very easy task. I think it is possible to basically emulate today's gasoline vehicle with a hybrid vehicle, but the cost is inherently more than a gasoline vehicle. With an electric vehicle, the cost isn't necessarily—there's nothing inherent about it that will make it more expensive.

So it seems that, with that complicated of a system, that it's a much bigger question, plus the fact that it doesn't get—it doesn't really get the best solution out of all this. You know, in the end, electric vehicles can really and truly be totally zero-emission. As we move the power plants to become cleaner than all the alternative energy-producing means, electric vehicles will continue to develop.

But the hybrid vehicle—to make a good hybrid vehicle, you've got to begin with a good electric vehicle. So the electric vehicle I think represents also the beginning of a hybrid vehicle, but we need to get the electric vehicle perfected and then I think it's easier to enter into looking at the hybrid concepts, while they're also working on small generators, APUs, at the same time.

So we're kind of mixed on that. We do not plan to get into hybrids directly in the near future, no.

Mr. EHLERS. Thank you.

Mr. Ovshinsky, I appreciated your comment about the periodic table. In the interest of time, I bit my tongue when Dr. Denman said we were limited by that. It's true there are only roughly 100 elements, but there's virtually an infinite number of combinations of those elements, and we haven't even begun to think about, let alone investigate, organic chemicals or chlorine-based chemicals in batteries. I have no idea whether there's anything there that will work, but you never know.

I did want to ask you specifically on the—most of the testimony we got today indicated the nickel metal hydride battery would be for the mid-term, not the short-term. My feeling was that it's ready now and it should be considered a short-term alternative rather than mid-term. You may have a biased view of that, but I'd still like your comments on that.

Mr. OVSHINSKY. Well, I would hope it's not biased, because what we have relied upon has been—our credibility has been established by what we've done and not by what we've said.

Mr. EHLERS. Yes.

Mr. OVSHINSKY. So I think that that's very important, to know that I am not here trying to plead the special cause. I am here to just report facts that aren't available probably to many people.

The near-term will have to go to whatever anybody has available, such as lead acid, because I think that—in order to give the engineers and the designers and the car makers something to put in the car, which is very, very important to start production. But no one I know really believes that lead acid is going to be a viable way of dealing with this problem. Therefore, it behooves us that—since we do have the solution, and we would have had the near-term battery if we would have been able to get the money sooner. So it behooves us to make sure that we get the production going, so that we can start filling the pipeline with cars with our battery, which we will sell to everybody, by the way; the GM-Ovonic company will sell to everybody.

We want to be sure that that happens, and that's why our battery is called mid-term, because realistically we have to be getting into production. I can just tell you that I am working with a splendid group of people from General Motors who are just doing a great job with us, and we're very committed to making sure that that happens. So we are a production company. We are not a research and development company.

Now I'd like to just say one more thing about the near-term, medium-term, and long-term. We feel—and we never went after that money at the time; probably we should have—we feel that we have the long-term battery. But I want to avoid the idea of having to promise things because I always felt that carrots belong on the luncheon table and not be handed out for people who want to raise money.

But I must tell you with all sincerity that I could make a very plausible scientific and technical argument to show you that the batteries can cost lower than anything that's been projected and the mileage can be much higher than anything projected. Those are my opinions. They are scientifically-based. I have a very good record.

But I did want to come and talk about long-term batteries because it's now, it's right now, and the middle-term that are very, very important. Get the process started to get that flywheel, if everybody excuses that expression, get that flywheel running, and, yes, I don't like moving parts. If they get the flywheel up to speed, then we'll have the inertia, as Mr. Williams says, in our favor because that will be an unstoppable combination.

Mr. EHLERS. I would just remind you, you have far more moving parts in your battery than—if you consider electrons. [Laughter.]

Mr. Chairman, Mr. Ovshinsky mentioned carrots, which reminded everyone here that they're hungry. In the interest of time and the gastrointestinal tracts of the people here, I have no further questions or comments. Thank you.

Mr. KLEIN. Well, thank you very much, Mr. Ehlers.

I have just two questions and then we do thank the entire panel.

Mr. Bradley and Mr. Worden both referred to what has been termed the "bottoms-up" approach in which there is a broad-based interaction between the agencies and various smaller companies. That seems to be in contrast with the DOE approach, which seems to be more of a tops-down. I would just wonder if any of the other panelists would like to comment on the merits of one versus the other approach to development of electric-powered vehicles. No takers? Mr. Ovshinsky?

Mr. OVSHINSKY. Well, I think that there are many roads to Mecca, and I believe that what we have to do is to try everything. And I think that I would like to encourage James—I was talking to him earlier—to get into designing a car from the bottom-up rather than just going out and taking other cars and making them into electric vehicles.

I believe small businesses are vital to this country. The innovator and the inventor are still a great part of the American tradition. I believe that there is a great deal to be had in terms of partnership between large companies and small companies. So I don't think that there is any one magic way of doing it, but I believe that all should be encouraged.

Mr. KLEIN. Let me ask just one final question. Is there anything that you would recommend—and I direct this to the entire panel—that we as a nation should be doing or that we in Congress should be doing to stimulate, to do whatever can be done to move ahead on this venture?

Mr. OVSHINSKY. I believe that we need investment. We need investment, and not preconceived notions. We don't need dogmas. All we need to do is to start this process going, so it can have a life of its own. And I believe we need the support of Congress and the President to make sure that there's a culture and an environment out there to understand that there's not only a social need, but an economic need for alternative energy and for an electric car.

Mr. WILLIAMS. I support Mr. Ovshinsky's comment. It's my experience that many of the good batteries that we find are not in this country. That distresses me, that we have to look elsewhere for the technology. It's the wrong thing to find. And when we find it, we intend to bring it back here.

But it's doubly distressing when we find that some of the technologies that are prospering in other parts of the world were invented in this country and got away. And you say, why is that?

Mr. KLEIN. It happens to us all the time.

Mr. WILLIAMS. It's my experience that we start out some good ideas and don't have the resolve and the commitment to see through the original plans because there will be a better idea and we'll go down a different road. And there are many ideas of how to take electric vehicles forward and how to clean up the air and where the new technology is, and we've gone down this road significantly. And I suggest we need the resolve and the commitment to see it through to our original goals.

Mr. BRADLEY. Mr. Chairman, if I can——

Mr. KLEIN. Sure.

Mr. BRADLEY. I think it's important to realize that I don't believe we'd be here today talking about battery advancements and electrical vehicle technology if California hadn't shown some leadership and set a performance standard that had to be met in 1998. Several—a couple of States have followed up on that. I think it's really to their benefit air quality-wise and probably economically beneficial to California, but it is to the rest of the country as well.

So I hope that the Federal Government maintains its support for setting these technology-forcing and maintaining these technology-forcing goals, so that it does stimulate the kind of investment in large and small corporations; it does stimulate fairly significant research programs and assistance programs from the Federal Government, from State governments, that can create the kind of inertia that John was speaking towards and the kind of cooperation and coordination that we're going to need to move forward. But it's that performance standard, that mandate, that has driven this process to date.

Mr. KLEIN. Thank you.

Any other comments? Mr. Worden?

Mr. WORDEN. Yes. I think it's really down to basics. The Federal funding for advanced development continuing—lowering the cost of the drive trains, as Dr. Denman brought up, is a key point. All the systems of the vehicle, lower the cost and reduce the energy use of all systems, ancillary systems, support systems of vehicles, eliminate them, reduce them, take the systems approach. Of course, there has to be battery research, but all these other things are important.

And, as various people have said, not large amounts of funding for a lot of these things, but small amounts at this point can make dramatic differences, as the ARPA program really exemplifies. Major Cope has a group of technical advisers that carefully listen to and set up programs with companies, large and small, to attack these things and solve them, and I don't think we should think of this as some kind of a battle of the Microsoft and the IBM, but there's no reason why we can't work together. And now that's actually our feeling, is let's look at these things, just the technical objectives of lowering the weight, raising the efficiency, use of new materials, the composite materials, all through the drive train and the ancillary components. That's what's going to make the vehicle really right.

Mr. KLEIN. Well, again, I thank all of you for the extremely helpful, informative, and provocative testimony.

And at this point, if there is no further business, the subcommittee stands adjourned, and Mr. Ehlers and the rest of us can all have our lunch.

[Whereupon, at 12:57 p.m., the subcommittee adjourned, subject to the call of the Chair.]

APPENDIX

Responses to additional questions submitted for the record by the U.S. Department of Energy

QUESTION SUBMITTED BY HONORABLE MARILYN LLOYD

Question 1: How much slippage has there been in the original timetable of the U.S. Advanced Battery Consortium (USABC)? In your written statement you say (p. 13): "Pilot plant production of at least one mid-term battery is expected in FY 1996-97." The original USABC timetable called for pilot-scale production of an advanced mid-term battery by 1994, did it not? Does this indicate that the program is now 2-3 years behind schedule?

Answer: Although it is not clear what was intended by the original USABC schedule, the current timetable for completing the mid-term battery development objectives has been delayed approximately one year. This delay is primarily due to the fact that it took much longer to negotiate the battery development contracts and obtain approval of the complex agreements than was anticipated. When the USABC was first being formed it was quoting a date for pilot production of mid-term batteries by 1994. It is our understanding that this date was based on the schedule requirements imposed by the California zero emission mandate beginning in 1998 and did not necessarily reflect what could reasonably be achieved from a technology standpoint. Pilot production in 1994 would have been an unusual achievement since the agreement with DOE was not signed until October 1991, and it takes approximately two years to design and build a full-scale battery pilot plant. Components for mid-term batteries are currently in pilot production. This includes sodium sulfur cells and nickel metal hydride electrodes.

However, further development is necessary before either of these batteries can satisfy all of the mid-term criteria, including cost and cycle life requirements. The development work is not expected to be completed until mid 1996. Excellent progress has been made with the mid-term technologies. The recent agreement between General Motors and The Ovonic Battery Company is an indication of this progress. General Motors has agreed to assist Ovonic in commercializing its nickel metal hydride battery and may decide to take the current technology to pilot production as an interim step.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 2: In the Department of Energy FY 1995 Congressional Budget Request, DOE's description of program activity in support of the $28.8 million budget request for the Battery Development component of the Electric and Hybrid Propulsion Development program states (Volume 4, p.479): "Contracts initiated in FY 1992-93 continue toward developing at least one mid-term battery system that will achieve pilot plant level production in 1995." Has the program experienced unanticipated delays since this budget document was submitted in February of this year that would account for the timetable for pilot plant production being pushed back from 1995 to 1996 or 1997?

Answer: The language in the FY 1995 budget reflects the original schedules established by the USABC with some delay factored in for the late initiation of the development contracts. Excellent progress has been and continues to be made, although some key problems still exist, primarily with cost and cycle life. It should be pointed out that pilot production of some components is already in place. Sodium sulfur cells and nickel metal hydride electrodes are already being made on pilot lines. However, pilot production of full battery packs that satisfy *all* of the mid-term criteria will not begin until the technical and cost issues are resolved. All of the mid-term criteria, especially cost, are required for an electric vehicle to be technically and economically viable. The current schedule for completion of these technical and cost issues is mid 1996. At that point the pilot process will begin for a battery that meets the definition of "mid term." However, it is possible that for business reasons an organization, such as the General Motors-Ovonic team or Silent Power and RWE, may decide to take a mid-term technology to pilot production before all of the cost issues are completely resolved. Although such a battery would not satisfy all of the economic requirements, it could temporarily fulfill a business need until further work can be done to bring cost into line. Because of the availability of these options, which are driven by business concern rather than technical or economic issues, it is difficult to establish an exact date for the initiation of pilot production. However, as indicated on page 5 of my prepared statement, our best estimate at this time is that pilot plant design for a battery that meets all mid-term criteria will begin in 1996.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 3: Have USABC battery development contractors failed to meet the terms of the contracts initiated in FY 1992-93 in such a way as to account for the apparent slippage in the timetable for development and production of an advanced mid-term battery?

Answer: As indicated previously, the major delays occurred during the negotiations of the subcontracts with the battery developers which took much longer than anticipated. The intellectual property provisions of these agreements were very complex, in some cases involving previous agreements between the contractor and foreign firms, third part rights, etc. Because of these delays the actual development did not get underway as expected. Since then, excellent progress has been made in bringing some of the technologies to the point where plans for commercialization have been initiated. This is the case with the Ovonic nickel metal hydride battery where General Motors has signed an agreement with Ovonic to assist them in commercializing this technology.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 4: In his written testimony, Mr. John Williams of General Motors Corporation, the Chairman of the USABC, says (pp.3-4): "Our initial estimate is that a pilot facility capable of producing 2,000-5,000 battery packs per year could be on-line by mid-1999." Can you clarify the apparent disagreement between Mr. Williams' target date of 1999 and yours of 1996-1997? Which is a more accurate representation of the USABC's planning and timetable?

Answer: My testimony and that of Mr. Williams are consistent. In my testimony, I said that pilot plant design for a mid-term battery system would be initiated in FY 1996. Mr. Williams' testimony included a chart showing pilot plant design starting in 1996 and pilot production beginning in 1999. It is anticipated that all of the technical and business (cost) requirements necessary to satisfy the mid-term criteria will not be completed until 1996. Pilot plant design will begin no later than that for a battery that can satisfy the mid-term criteria, although the auto industry's use of concurrent engineering practices means that plant design could begin sooner. As stated previously, pilot plant production for any one of the mid-term battery technologies could be initiated at an earlier date even though the battery does not fully meet the mid-term criteria. DOE is hopeful that this will be the case and that is what I was referring to in my written testimony submitted for the record.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 5:	You stated in response to a question at the hearing that "vehicles which have current or near-term lead acid battery technology most likely would provide the propulsion mechanism for the vehicles that would be available in 1998." How does this square with the Department's statement that the advanced battery technology R&D program should be measured by its "support of California's requirement for zero emission (electric) vehicles in 1998." (FY 1995 Congressional Budget Request, Volume 4, p.436, "Performance Measures")?
Answer:	The battery development program with the USABC has always been focused on trying to provide advanced battery technologies that could be used in vehicles for the California zero emission mandates beginning in 1998. However, as stated in the response to the previous questions, it is not likely that a battery that satisfies the mid-term cost criteria will be available in time for the initial introduction of the vehicles at the beginning of the mandate. Consequently, the vehicle manufacturers will initially have to either use the best available lead acid batteries or select a mid-term technology that will provide improved performance but at a very high cost. This is a business decision that the vehicle manufacturers must face. As I stated, a likely choice would be the low cost lead acid battery, even though the vehicles would not provide the desired performance.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 6: The USABC has chosen to emphasize mid-term and long-term technologies. In light of the program performance measure cited in question #5 above, why has DOE chosen not to support research to optimize lead acid batteries for electric vehicles? Could a relatively small Federal investment expedite the development of advanced lead acid technology to help meet the 1998 zero-emission vehicle mandate?

Answer: The Department supported improvements in lead acid technology for over a decade. Significant advances were made during that period. However, the automotive industry specifically asked DOE in 1991 to assist it with advanced batteries. Its view was that it could work directly with the developers of lead acid batteries to assure their availability for the 1998 zero emission vehicle mandate if advanced batteries are not ready for production by the time the mandate becomes effective. It should be noted that a number of battery companies have continued to develop lead acid technology without government assistance. It is the industry's opinion that lead acid batteries, even with the projected improvements, cannot store enough energy for electric vehicles to achieve wide public acceptance. The Department concurs with this opinion. The Department, in cooperation with the USABC, has made publicly available all of its testing methods technology to assist industry in the development of lead acid and other near-term batteries.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 7: In your testimony you said that the Department plans to acquire significantly more electric vehicles for the Federal fleet in FY 1995 than you did in FY 1994. What are the Department's plans for acquiring electric vehicles next year?

Answer: The Department tentatively plans to buy 100 to 150 electric vehicles in FY 1995. Originally, these were to be a mix of vehicles for the Site Operators Program and the Federal Fleet Executive Order Program. The Department has held discussions with the electric utility industry, as represented by EV America, concerning an accelerated program to purchase electric vehicles for the Federal fleet.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 8: What is the status of the Department's electric vehicle demonstration program, as mandated by Title VI, Subtitle A of the Energy Policy Act?

Answer: Funds have not been appropriated for the implementation of Title VI, Subtitle A of the Energy Policy Act. We have received funding to continue similar activities through the DOE Site Operators Program and the Federal Fleet Executive Order Program.

QUESTIONS SUBMITTED BY CONGRESSWOMAN MARILYN LLOYD

Question 9: How many cars should be available to conduct a demonstration program? Are they available?

Answer: The number of vehicles required for a demonstration program is a function of the planned objectives. To achieve public response to a particular technology may require no more than 50 to 100 vehicles, such as the General Motors PREview Program and the Ford demonstration program. However, if the intent is to promote commercialization and leverage production, it may require several thousand vehicles to get the process initiated and drive the cost down through the economies of scale achieved by increasing production volumes.

QUESTIONS SUBMITTED BY REPUBLICAN MEMBERS

Question 1: Do you intend to continue the use of the Site Operators Program as the main method of Government-supported EV and infrastructure demonstration?

Answer: The Department plans to use the resources, experience, and capabilities within the ongoing Site Operators Program and the Federal Fleet Executive Order Program for implementing future electric vehicle and infrastructure demonstrations.

QUESTIONS SUBMITTED BY REPUBLICAN MEMBERS

Question 2: How many site operators are participating in the Site Operators Program, what funding is DOE providing, and what cost sharing is involved?

Answer: The current roster of DOE site operators includes 13 sites. DOE provided the Site Operators Program with $1.8 million in FY 1994. The site operators on average provided about $2 for every $1 of government funds. At least one site provides approximately $10 for every $1 of government funds.

QUESTIONS SUBMITTED BY REPUBLICAN MEMBERS

Question 3: On pages 16 and 17 of your testimony, you state that, under the Federal Fleet acquisition program, DOE is planning to provide funding for 10 to 15 EVs for several different Federal agencies in FY 1994, and is planning expanded introduction in FY 1995. From whom will these EVs be purchased and at what cost?

Answer: In FY 1994, a total of 10 vehicles are being purchased from U.S. Electricar of California and Spartan Motors of Michigan at a cost of $45,000 per vehicle. These vehicles will go to the General Services Administration, Department of the Air Force, Department of the Navy, and Department of the Interior. In FY 1995, from 100 to 150 electric vehicles may be purchased through the Federal Fleet Executive Order Program in support of the EV America initiative.

QUESTIONS SUBMITTED BY REPUBLICAN MEMBERS

Question 4: Is the battery technology being developed for EVs applicable to hybrids? What, if any, are the different performance requirements for hybrid vehicle batteries?

Answer: The battery technology currently being developed for electric vehicles by the USABC can be applicable to hybrids. Some of the ongoing battery research is focused on battery types that can also be designed to perform as a high power device required for hybrid service. The USABC has agreed to assist the Partnership for a New Generation of Vehicles industry team in this matter when new funding is available in FY 1996.

The performance requirement for electric vehicles is based on the amount of energy that can be stored, rather than how fast it can be delivered from or returned to storage. This "power" requirement is critical to a hybrid propulsion system because the battery size, in terms of energy stored, will be a fraction (10 to 20 percent) of that for an electric vehicle, but still must deliver full power for acceleration.

QUESTIONS SUBMITTED BY REPUBLICAN MEMBERS

Question 5: What is the current status of hybrid vehicle development relative to EV development?

Answer: The hybrid propulsion systems under development by General Motors and Ford are "electric based" and extensions of the systems developed for their electric vehicles. The addition of an onboard electrical generation system that utilizes liquid or gaseous fuel for vehicle range is a higher level of complexity than battery only electric propulsion. The hybrid represents the next generation in a continuum of "electric based" vehicle technologies, which also includes the fuel cell. Electric vehicles are nearing production in response to the 1998 California mandate. Hybrid vehicles will be at a similar level of development by the year 2001 to 2003.

EPA's RESPONSES TO QUESTIONS FROM THE JUNE 30,1994 HEARING ON ELECTRIC VEHICLES AND ADVANCED BATTERY R&D

Questions from Chairman Lloyd:

1. Does the Environmental Protection Agency's review of Ozone Transport Region policy options include a technology assessment component? In particular, will EPA's decision on the Ozone Transport Commission petition be supported by a comparative assessment of the potential for reduced emissions associated with alternative motor vehicle technologies, and the costs associated with these reductions?

2. If so, who develops this assessment for EPA? Is EPA's technology assessment method comparable with the approach used in the California Air Resources Board staff technology assessment report presented in conjunction with CARB's 1994 policy review of the California Low Emission Vehicle and Zero Emission Vehicle requirements?

Responses to Questions 1 and 2:

EPA is presently assessing the OTC LEV program and alternatives. Attached is a report prepared for EPA titled, Analysis of Costs, Benefits, and Feasibility Regarding Implementation of OTC Petition on California Low Emission Vehicles completed by E.H. Pechan & Associates, Inc. In addition, a copy of a recent assessment by EPA's Office of Mobile Sources titled, "Update of Emissions Estimates for OTC/LEV and National LEV Programs in the Ozone Transport Region" is provided for your review. The EPA assessment is comparable to the CARB report.

Follow-up Questions from Republican Member:

1. Will the EPA decision on the OTC petition be binding on all the member States and the District of Columbia, even for the 4 States (New Hampshire, Delaware, New Jersey and Virginia) that voted against the recommendation?

Yes. If the petition were approved by EPA, the Agency would issue a State Implementation Plan (SIP) call to each of the member states of the OTC which would require them to modify their SIPs reflecting the emissions program requested in the petition.

2. Who at EPA will make the decision on the OTC petition? Will this decision be made at the EPA Regional Office level, or will it be made by the Administrator?

The Clean Air Act requires the decision to be made by the Administrator.

3. Other than conducting public hearings and public round table meetings, what other steps is EPA taking to assess the OTC petition? Are any analytical studies being carried out, and if so, by whom?

EPA's Office of Mobile Sources and Office of Air Quality Planning and Standards have conducted detailed analysis concerning the necessity, expected emissions consequences of the LEV program, and the emissions inventory in the Northeast. In addition, as part of the regulatory analysis required by this rulemaking an EPA contractor, E.H. Pechan & Associates, Inc. has prepared an analysis of costs, benefits and feasibility regarding the implementation of the OTC LEV petition.

4. Will the EPA determination on the OTC petition be final, or is it subject to appeal and/or to possible litigation?

The Administrator's decision would conclude the rulemaking under the section 184 petition process. As an administrative rulemaking it would be subject to judicial review.

5. You note on page 4 of your testimony that, regardless of the final disposition of the OTC petition, it is clear that additional measures will be necessary if the region is to reach and maintain attainment. What might these additional measures include?

Based on EPA's region-wide modeling analysis, it is clear that very large reductions are necessary to bring the region into attainment. Based on currently available modeling EPA believes that at least a 50% to 75% reduction in emissions is needed for attainment from the 1990 baseline. Additional measures would include all the measures required under the 1990 Clean Air Act Amendments and additional controls on non-road emissions and stationary source controls.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

SEP 30 1994

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Update of Emissions Estimates for OTC/LEV and National LEV Programs in the Ozone Transport Region

FROM: Office of Mobile Sources

TO: Subcommittee and Work Group Members on Mobile Source Emissions and Air Quality in the Northeast States

On July 12, 1994 the EPA Office of Mobile Sources (OMS) released a memorandum providing emission estimates for the Ozone Transport Commission OTC LEV Program and several scenarios related to an alternative program of national standards. Since then, these alternative standard proposals have changed and OMS has worked to refine the original analysis to incorporate some of the issues raised in response to its release.

The process of refining the analysis is not necessarily complete, and further analysis will be needed if there are changes in the proposed alternatives to the OTC LEV program. However, the attached tables give EPA's current best estimates of the emissions benefits of the various programs given the specific assumptions detailed in the attachment. This analysis is an approximation of the emissions under the various scenarios in order to illustrate their relative impacts. It is not meant to replace the more complete analyses needed for inventory creation, air quality modeling, or for any SIP submission.

Two major issues concerning the national standards alternative remain unresolved. These are: the mechanism for enforcing the program prior to the 2004 model year, and the circumstances under which these vehicles would have California OBD (or its equivalent). If these issues are not resolved, the benefits of the national alternative will be substantially smaller than what is shown in this analysis. In presenting these emission estimates, EPA is highlighting the importance of resolving these issues related to the current proposals.

This memorandum will be followed by a more detailed memorandum on the methodology used for the assessment of migration and tourism impacts.

Attachments

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Key to Tables of Emission Benefits for OTC/LEV and National LEV Programs in the Ozone Transport Region

- All cases assume federal reformulated gasoline throughout the OTR.

- All cases assume that within the OTR, 85% of vehicles are subject to enhanced I/M programs, while 15% are subject to no I/M programs.

- Tier 1, OTC LEV + ZEV, and OTC LEV cases all assume a LEV program in New York and Massachusetts beginning in 1996.

- OTC LEV + ZEVs assumes a program meeting California NMOG fleet average exhaust standards beginning in 1999, including the ZEV sales mandate, and meeting all of the requirements of the April 8 LEV Credit Guidance Memo.

- OTC LEV assumes a program meeting California NMOG fleet average exhaust standards beginning in 1999, and meeting all of the requirements of the April 8 LEV Credit Guidance Memo, with no ZEVs.

- National LEV Alternative assumes:

    - No separate LEV program in New York and Massachusetts

    - California OBD (or its equivalent)

    - Federal reformulated gasoline

    - State programs in enhanced I/M areas meeting all requirements of the April 8 LEV Credit Guidance Memo

    - In the OTR:

        - 40% TLEVs for model years 1997-2000
        - 30% LEVs for model year 1999
        - 60% LEVs for model year 2000
        - 100% LEVs for model years 2001 and later

    - Outside the OTR:

        - Program begins in 2001 with 100% LEVs

- For permanent migration, 7.25% of the OTR fleet is assumed to consist of vehicles originally sold outside the OTR.

    - 85% of these vehicles are subject to enhanced I/M, 15% to no I/M program.

For temporary visitation (tourism and business travel), 4.1% of VMT is assumed to be from vehicles from outside the OTR.

- None of these vehicles are assumed to be subject to enhanced I/M programs.

Emission Estimates for LEV and FedLEV Programs in the Ozone Transport Region

(assuming Federal RFG throughout the OTR, and that all LEVs, including those in the current industry proposal, have California-type OBD systems)

VOC Emissions (tons/day) for Passenger Cars and Light Duty Trucks (< 6000 lbs.) in the OTR

	Without Migration or Tourism				With Migration				With Migration and Tourism			
Year	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal
1990	4,527	4,527	4,527	4,527	4,527	4,527	4,527	4,527	4,536	4,536	4,536	4,536
1996	1,809	1,809	1,809	1,610	1,809	1,809	1,809	1,610	1,826	1,826	1,826	1,827
1999	1,536	1,530	1,530	1,526	1,536	1,531	1,531	1,527	1,559	1,554	1,554	1,550
2002	1,165	1,117	1,119	1,115	1,168	1,123	1,125	1,119	1,191	1,148	1,150	1,143
2005	1,027	909	910	914	1,033	923	925	920	1,059	954	955	949
2007	971	807	812	617	976	827	831	822	1,007	861	866	854
2010	907	672	679	694	918	699	706	699	949	739	746	736
2015	697	585	596	623	911	621	631	624	945	667	677	666

NOx Emissions (tons/day) for Passenger Cars and Light Duty Trucks (< 6000 lbs.) in the OTR

	Without Migration or Tourism				With Migration				With Migration and Tourism			
Year	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal
1990	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,967	1,967	1,967	1,967
1996	1,809	1,809	1,809	1,809	1,809	1,809	1,809	1,809	1,616	1,616	1,816	1,616
1999	1,626	1,618	1,618	1,621	1,627	1,619	1,619	1,623	1,639	1,632	1,632	1,635
2002	1,490	1,407	1,409	1,424	1,491	1,417	1,419	1,430	1,508	1,436	1,438	1,448
2005	1,394	1,175	1,179	1,201	1,396	1,200	1,203	1,210	1,416	1,229	1,233	1,235
2007	1,346	1,041	1,052	1,062	1,349	1,075	1,085	1,070	1,373	1,110	1,120	1,101
2010	1,292	854	865	887	1,296	904	914	896	1,324	948	958	936
2015	1,297	706	724	747	1,302	773	789	750	1,335	627	842	798

Emission Estimates for LEV and FedLEV Programs in the Ozone Transport Region
(assuming Federal RFG throughout the OTR, and that all LEVs, including those in the current industry proposal, have California-type OBD systems)

Fleet Average VOC Emissions (g/mi) for Passenger Cars and Light Duty Trucks (< 6000 lbs.) in the OTR

	Without Migration or Tourism				With Migration				With Migration and Tourism			
Year	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal
1990	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.34	4.34	4.34	4.34
1996	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.57	1.57	1.58
1999	1.26	1.26	1.26	1.25	1.26	1.26	1.26	1.25	1.28	1.28	1.28	1.27
2002	0.92	0.88	0.88	0.88	0.92	0.88	0.88	0.88	0.94	0.90	0.90	0.90
2005	0.78	0.69	0.69	0.69	0.78	0.70	0.70	0.69	0.80	0.72	0.72	0.72
2007	0.71	0.59	0.60	0.60	0.72	0.61	0.61	0.60	0.74	0.63	0.64	0.63
2010	0.64	0.47	0.48	0.49	0.65	0.49	0.50	0.49	0.67	0.52	0.53	0.52
2015	0.60	0.39	0.40	0.41	0.60	0.41	0.42	0.41	0.63	0.44	0.45	0.44

Fleet Average NOx Emissions (g/mi) for Passenger Cars and Light Duty Trucks (< 6000 lbs.) in the OTR

	Without Migration or Tourism				With Migration				With Migration and Tourism			
Year	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal	Tier 1	OTC LEV + ZEV	OTC LEV	National Alternative Proposal
1990	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
1996	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.57	1.57	1.57
1999	1.34	1.33	1.33	1.33	1.34	1.33	1.33	1.33	1.35	1.34	1.34	1.34
2002	1.17	1.11	1.11	1.12	1.17	1.11	1.12	1.12	1.19	1.13	1.13	1.14
2005	1.05	0.89	0.89	0.91	1.05	0.91	0.91	0.91	1.07	0.93	0.93	0.93
2007	0.99	0.77	0.77	0.78	0.99	0.79	0.80	0.79	1.01	0.82	0.82	0.81
2010	0.91	0.60	0.61	0.63	0.92	0.64	0.65	0.63	0.94	0.67	0.68	0.66
2015	0.86	0.47	0.48	0.50	0.87	0.51	0.52	0.50	0.89	0.55	0.56	0.53

HON. MARILYN LLOYD
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY

Hearing on Electric Vehicles and Advanced Battery R&D
Additional Questions for the Record

Mr. Stanford R. Ovshinsky, President and Chief Executive Officer, Energy Conversion Devices, Inc. and Chairman and Chief Executive Officer, Ovonic Battery Company, Inc.:

1. How many of your batteries and EV battery packs have been ordered by the U.S. Advanced Battery Consortium? How many have been installed in vehicles to date?

2. Has the GM-Ovonic joint venture determined where its manufacturing facility will be located?

3. What is your estimate of how long it will take to get a production facility up to the point of providing sufficient numbers of batteries to meet California and other state requirements? How many batteries must be produced before you reach economies of scale necessary to bring down costs to a level that will enable EVs to be viable in the marketplace?

4. Can you be ready by 1998? What interim timetable of key steps would be needed in order to accomplish this?

5. Can you explain how you will be able to make the Ovonic batteries available to firms other than those in the USABC if the batteries are being developed with the assistance of USABC funding?

ADDITIONAL QUESTIONS FOR THE RECORD

Q1. How many of your batteries and EV battery packs have been ordered by the U.S. Advanced Battery Consortium? How many have been installed in vehicles to date?

A1. 5 EV battery packs have been ordered and 5 have been delivered. All are on test and 4 have been installed in vehicles to date. In addition, car companies have ordered EV batteries directly, these batteries are currently being tested in EVs.

Q2. Has the GM-Ovonic joint venture determined where its manufacturing facility will be located?

A2. GM Ovonic is in the process of determining the site of its manufacturing facility at this time.

Q3. What is your estimate of how long it will take to get a production facility up to the point of providing sufficient numbers of batteries to meet California and other state requirements? How many batteries must be produced before you reach economies of scale necessary to bring down costs to a level that will enable EVs to be viable in the marketplace?

A3. We intend and expect to be able to provide in volume at competitive prices batteries to meet the 1998 mandate in California and other states as needed. Price data at this time is proprietary to GM Ovonic.

Q4. Can you be ready by 1998? What interim timetable of key steps would be needed in order to accomplish this?

A4. Yes. The details of meeting the 1998 production levels are proprietary to GM Ovonic and cannot be disclosed at this time.

Q5. Can you explain how you will be able to make the Ovonic batteries available to firms other than those in the USABC if the batteries are being developed with the assistance of USABC funding?

A5. Our contract with USABC provides that our company retain the patent rights to our battery technology. USABC partners have have certain competitive advantages over other customers. USABC partners also have an option to acquire a license from OBC to manufacture Ovonic batteries for use in their own EVs. OBC can license the battery technology and sell batteries to other companies. GM Ovonic has already announced it will sell batteries to all companies who wish to purchase them.

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY

HEARING
ON
ELECTRIC VEHICLES AND ADVANCED BATTERY R&D

June 30, 1994

Republican Member Followup Questions Submitted to

Stanford R. Ovshinsky, President and Chief Executive Officer (CEO) of Energy Conversion Devices, Inc., and Chairman and CEO of Ovonic Battery Company, Inc.

1. What are the advantages of the metal hydride (MH) electrode for materials engineering and optimization when compared with negative electrodes for other nickel-based battery systems?

2. What are the material requirements for the MH materials used for an NiMH battery electrode?

3. What are the environmental impacts of the eventual disposal of the Ovonic NiMH battery?

4. You note on page 4 of your testimony that the assembly of your EV batteries has been primarily carried out by hand and limited to prototype production, but that, with GM Ovonic, you are setting up manufacturing facilities. What volumes of batteries will these facilities be capable of producing?

5. On page 5 of your testimony you state that with adequate R&D support, you believe that the Ovonic NiMH battery can be further developed to meet or exceed the USABC long-term goals. What level of support is required, and in what time frame do you believe you could meet or exceed the USABC long-term goals?

REPUBLICAN MEMBER FOLLOWUP QUESTIONS

Q1. What are the advantages of the metal hydride (MH) electrode for materials engineering and optimization when compared with negative electrodes for other nickel-based battery systems?

A1. The MH electrode offers an important opportunity for materials engineering and optimization when compared with negative electrodes for other nickel-based battery systems. In these other systems, the negative electrode (Cd, Zn, or Fe) is typically fabricated from relatively pure elemental metals, and the oxidation-reduction reactions associated with battery charge and discharge convert the electrode back and forth between a metal and a metal oxide that is a poor electric conductor. This type of chemical reaction can be undesirable in a practical battery design because of accompanying changes in the physical properties of the electrode. Changes in the mechanical integrity and surface morphology of the electrode as a result of dissolution and recrystallization and of its reduced electrical conductivity in the oxidized state are sources of many of the performance deficiencies in these systems.

The MH electrode, by contrast, uses a chemical reaction that reversibly incorporates hydrogen into a metal alloy. In this oxidation-reduction reaction both chemical states are metallic, and so electrical conductivity is high in both the charged and discharged states. Furthermore, the small size of the hydrogen atom allows it to enter the metal lattice during formation of the hydride (reduced) state with only about 10% volumetric expansion and without the changes in crystallography associated with oxidation and reduction of the Cd, Zn, or Fe electrodes.

In effect, the MH negative electrode can be regarded as a matrix for the chemical incorporation of the hydrogen atom. In the Ovonic NiMH battery, we have exploited the ability of this matrix to be engineered through the use of multi-element alloys, using compositional and structural disorder to produce materials with desirable battery properties.

Q2. What are the material requirements for the MH materials used for an NiMH battery electrode?

A2. We use nickel, vanadium, zirconium, titanium, chromium, cobalt, manganese, iron and aluminum metals as the raw materials in the metal hydride alloy. These materials are readily available on a global basis in abundant quantities.

Q3. What are the environmental impacts of the eventual disposal of the Ovonic NiMH battery?

A3. The environmental impact of eventual disposal of the Ovonic NiMH battery was subjected to independent testing with results presented at The Proceedings of Battery Waste Management Seminars, 1990 and 1991. According to existing EPA regulations, batteries that use this technology can be safely disposed of in landfills. It was also shown that with existing technology, Ovonic NiMH batteries can be recycled into metallurgical additives for cast iron, stainless steel, or new Ovonic NiMH battery electrodes. The commercial viability of each of these technologically feasible recycling programs will depend on process economics.

Q4. You note on page 4 of your testimony that the assembly of your EV batteries has been primarily carried out by hand and limited to prototype production, but that, with GM Ovonic, you are setting up manufacturing facilities. What volumes of batteries will these facilities be capable of producing?

A4. We intend to meet market demands, including the demands established by California and other states with ZEV sales mandates. Detailed production plans are proprietary to GM Ovonic.

Q5. On page 5 of your testimony you state that with adequate R&D support, you believe that the Ovonic NiMH battery can be further developed to meet or exceed the USABC long-term goals. What level of support is required, and in what time frame to you believe you could meet or exceed the USABC long-term goals?

A5. We would need $30,000,000 and two years.

HON. MARILYN LLOYD
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY

Hearing on Electric Vehicles and Advanced Battery R&D
Additional Questions for the Record

Mr. James D. Worden, Chief Executive Officer, Solectria Corporation:

1. You say on page 7 of your written statement that programs at NIST and DOE to develop composite materials for car bodies "appear to be closed off to companies outside of the Big Three automakers." Please explain this statement further. What has been your firm's experience with NIST and DOE programs?

2. You applaud ARPA for its success in developing an industry and for fostering joint product development. What is your thinking on whether the "bottom up" approach used by ARPA is superior to the "top down" approach used by DOE?

3. You state in your testimony that the U.S. auto industry produces fewer than 10,000 electric vehicles annually. In your opinion, is it possible to produce the 35,000 EVs needed to meet the California Zero Emission Vehicle requirement by 1998? Where will the cars come from?

4. What is your battery of choice? Do you expect that the nickel-metal hydride battery will replace the lead-acid battery in the cars you produce? If so, in your opinion, when will the nickel-metal hydride battery be ready for widespread use?

5. Which do you expect will be the battery of choice to meet the California ZEV requirements?

6. Is there widespread utility interest in the development and deployment of electric vehicles? What do you see as the appropriate role of the utilities in EV deployment?

7. What uses do the utilities make of the cars you provide? Are they test vehicles? Do they serve educational purposes? Public relations?

8. How do you see your company and others working with the Partnership for a New Generation of Vehicles--the President's clean car initiative? What role should you play?

Ovonics

Response to the Questions of the Honorable Marilyn Lloyd
Committee on Science, Space and Technology
Subcommittee on Energy

1. Our contact with NIST has been quite limited, and we have had a little more interaction with the Department of Energy. Unfortunately, most of our discussions with both agencies have not been particularly fruitful. Increasingly, what we are hearing is that if we are not doing work as part of the Partnership for a New Generation of Vehicles (PNGV), there is no funding available. In conversations with the Department of Commerce, it has been reiterated that decisions on PNGV is a joint effort between the Big Three automakers and the federal government. Other companies are involved only to the extent that they can support Big Three programs.

2. It is important to note, at the outset, that all of my comments are only related to ARPA's Electric and Hybrid Vehicle Program. I am not familiar enough with how the rest of ARPA's programs have worked in the past.

The DOE's "tops-down" approach is more characteristic of large government-funded programs from the past. Indeed, such approaches have led to major technology advances, like getting the man on the moon. However, the car market is quite different from that. Large bureaucratic programs, where decisions are reached after weeks and months of bargaining among players, may not be the best approach. ARPA's approach allows dollars to flow much more directly to real technology development, and essentially allows firms who win awards under the program a great deal of freedom in reaching their objectives.

3. We believe that it will be quite possible for automakers to meet the 1998 California ZEV requirement. Each of the manufacturers affected by the mandate will have to produce between 2,000 and 6,000 vehicles per year in California from 1998 to 2000. By way of comparison, the US automakers produce around 250,000 vehicles per week! The Japanese manufacturers, especially Honda, have appeared quite willing and able to meet their mandated numbers. If the major US automakers appear unwilling or unable to produce the required vehicles, there are a number of firms willing to step up to the plate.

4. Currently, our production vehicles use either lead-acid batteries or nickel-cadmium batteries. While nickel-cadmium batteries offer improved energy density, power density, and life over lead-acid, their costs are so high that most of our customers opt for lead-acid.

If nickel-metal hydride batteries can be produced at a price close to the USABC targets, they will dramatically expand the potential applications of EVs. At the very least, they are likely to replace lead-acid batteries for all but a few vehicle applications.

We cannot offer an informed opinion as to when the battery will be ready for widespread use. We would defer to Stanford Ovshinsky, CEO of Energy Conversion Devices, or a representative of GM-Ovonic.

5. If nickel-metal hydride batteries are available for 1998, it is likely that they would be the batteries of choice. If not, we believe that it may be an advanced lead-acid battery that will power most EVs down the road.

At this point, there do not appear to be many other viable technologies that will be ready to meet the demands of the early years of the CARB mandate. However, beyond that, there are a host of battery alternatives that may provide a solution.

Ovonics

6. There is widespread utility interest in the development and deployment of electric vehicles, although the amount of involvement differs widely from company to company. Many of the utilities are taking a wait-and-see approach. However, there are many utilities taking a much more active approach. Their efforts can be categorized into three general areas:

- Infrastructure Development.
  Many utilities are investing in and installing charging outlets in their service territory

- Technology Development
  Some utilities are funding the development of key enabling technologies for electric vehicles--e.g., batteries, chargers, components, lightweight materials

- Public Awareness and Incentive Programs

Utilities that have been the most active include Boston Edison, Virginia Power, Georgia Power, Florida Power and Light, the Potomac Electric and Power Company and the Sacramento Municipal Utility District.

7. Our utility customers are using our vehicles for several purposes. Our first customers from three years ago started using the vehicles we provided primarily to learn about EVs and for public awareness and public relations. Several were sold to utility R&D programs as well.

Over the past year, our customers have been looking for vehicles to use in their general fleet.

8. We hope that we can play a role in the Partnership for a New Generation of Vehicles. Unfortunately, as of yet, we have not been invited to participate in the program. At this point, as an external observer, it is difficult to figure out exactly what the PNGV is doing, and how the agenda is being set. While PNGV has been capturing a large amount of government resources, we are concerned about how those resources are being allocated. As I mentioned earlier, designing and building advanced vehicles is quite different than putting a man on the moon. If PNGV is to take 8-10 years, and will only yield prototypes 5-6 years from now, it may end up being too little, too late.

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY

HEARING
ON
ELECTRIC VEHICLES AND ADVANCED BATTERY R&D

June 30, 1994

Republican Member Followup Questions Submitted to

James D. Worden, CEO & Director of R&D, Solectria Corporation

1. You say that the Force currently costs $26,050. Does this include the cost of the battery, and if so, what type of battery?

2. What is the cost of your E-10 truck?

3. On page 7 of your testimony, you say that the composite vehicle efforts at the National Institute of Standards and Technology (NIST) and DOE "appear to be closed off to companies outside of the Big Three automakers." Please elaborate on the statement.

4. Could you please go into more detail as to why you believe the ARPA program to be superior to the DOE program?

5. In your opinion, will there be sufficient EV manufacturing capacity available to meet the expected EV demand in excess of 100,000 vehicles required to meet the California EV standards adopted in California and in other States shortly after the year 2000?

Response to the Republican Member Followup Questions
Committee on Science, Space and Technology
Subcommittee on Energy

1. The Force price indicated includes the cost of a lead-acid battery.

2. The E-10 currently costs approximately $43,000. This cost is considerably higher than what we expect in larger volume production.

3. Much of what we have heard out of the DOE and NIST are large-scale research programs that have been designed by and for the large companies.. A case in point was the Department of Energy's Hybrid Program, where only proposals from teams which included one of the Big Three were accepted. In the Department of Energy's recent acquisition of electric vehicles for the Site Operator Program, only companies using suppliers to the Big Three EV programs were allowed to bid. Although we had a better track record and amount of experience, we were not even given the opportunity to respond to the solicitation.

4. ARPA's program is significantly less leaner than the DOE's programs. ARPA Instead of large, multi-million dollar multi-year programs, ARPA is funding a number of smaller R&D programs by private companies around the country. It is also willing to work with a wide range of companies who have key technological capabilities. Rather than federal resources being spent on meetings, paperwork, and overhead, they are going directly to research. ARPA's decentralized program places a strong emphasis on commercialization of funded development products. We think that in the rapidly moving, dynamic vehicle marketplace, this approach may lead to more optimal outcomes.

5. We feel that there will be sufficient capacity to meet the expected EV demand. There are a large number of companies around the world who are poised to enter this market, outside of the three major American automakers. Many are waiting to see what the Big Three will do, and are also hedging their bets until the EPA reaches a decision about the OTC.

NORTHEAST STATES FOR COORDINATED AIR USE MANAGEMENT
(NESCAUM)

MEMBERS:
CONNECTICUT BUREAU OF AIR MANAGEMENT
MAINE BUREAU OF AIR QUALITY CONTROL
MASSACHUSETTS DIVISION OF AIR QUALITY CONTROL
NEW HAMPSHIRE AIR RESOURCES DIVISION
NEW JERSEY OFFICE OF ENERGY
NEW YORK DIVISION OF AIR RESOURCES
RHODE ISLAND DIVISION OF AIR RESOURCES
VERMONT AIR POLLUTION CONTROL DIVISION

Response of Jason Grumet, Executive Director, NESCAUM

to Additional Questions for the Record posed by Hon. Marilyn Lloyd

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY

Hearing on Electric Vehicles and Advanced Battery R&D

1. In your written testimony you say that Zero Emission Vehicle mandates in New York and Massachusetts will require the sale of 100,000 ZEVs annually by the year 2003. According to Mr. Worden's testimony, the U.S. EV industry produces fewer than 10,000 vehicles per year. Where are the vehicles going to come from to meet the ZEV mandates?

Although current production of EVs is quite limited, we expect to see a significant increase in the rate of introduction of new, less expensive, and higher performance EVs in the 1-2 years preceding the initiation of the EV mandate. We expect that these vehicles will be introduced by established automakers as well as smaller business such as Solectria. The latter may purchase "gliders" from established automakers and may also pursue ground-up vehicles. In recent months, there have been encouraging reports that one or more major domestic automakers plan to enter into agreements to sell "gliders" to these smaller manufacturers.

2. You mention State-level purchases of ZEV fleet vehicles as an incentive to accelerate production. What would you project as the proportion of fleet ZEVs and non-fleet ZEVs that will be sold to meet the 2003 mandate in New York?

NESCAUM has not attempted to make such a comparison, but expects that by 2003, non-fleet purchases would almost certainly be needed to comply with a 10% sales level.

3. What would you project as the scale of production needed in order to bring costs down to a level that will make EVs competitive in the marketplace?

There are differences between expected production processes for EVs and those currently employed for conventional vehicles that make it difficult to predict at what point the two will be equal in cost. Furthermore, results may vary depending on whether the measure employed is purchase price or life-cycle cost. A recent study[1] prepared for the Northeast Alternative Vehicle Consortium (NAVC) predicts that economies of scale realized by 1998 will bring the purchase price of a conversion EV currently marketed for $22,500 down to $12,500. The same report predicts that EV life-cycle costs will be reduced to $0.17/mile by 1998, as compared to $0.16/milefor a comparable conventional vehicle. NESCAUM notes that recent press reports indicate that Solectria expects to offer a $20,000 four-passenger ground-up EV by 1997 if 20,000 initial orders are received.

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[1] Moomaw, et. al (for NAVC), *Near-Term Electric Vehicle Costs*, October 1994.

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4. You applaud the ARPA model for ZEV development. What is your perspective on the U.S. Advanced Battery Consortium effort?

In NESCAUM's view, U.S. ABC as fulfilled a critical role in bringing together a range of interests to develop battery performance goals and focus resources on specific technologies that may hold great promise. However, U.S. ABC does not appear to have been as quick to react to several rapidly evolving alternative energy storage technologies, some of which are being developed by very small businesses without strong connections to the major participants in the consortium.

NORTHEAST STATES FOR COORDINATED AIR USE MANAGEMENT
(NESCAUM)

MEMBERS:
CONNECTICUT BUREAU OF AIR MANAGEMENT
MAINE BUREAU OF AIR QUALITY CONTROL
MASSACHUSETTS DIVISION OF AIR QUALITY CONTROL
NEW HAMPSHIRE AIR RESOURCES DIVISION
NEW JERSEY OFFICE OF ENERGY
NEW YORK DIVISION OF AIR RESOURCES
RHODE ISLAND DIVISION OF AIR RESOURCES
VERMONT AIR POLLUTION CONTROL DIVISION

Response of Jason Grumet, Executive Director, NESCAUM

to Republican Member Follow-up Questions

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY

Hearing on Electric Vehicles and Advanced Battery R&D

1. *How much additional electric generating capacity will be needed in the NESCAUM region if the EV mandate is adopted, assuming that most EV battery charging occurs off-peak?*

   A report prepared in 1992 for NESCAUM[2] indicates that with full implementation of the ZEV mandate in the Northeast, and with recharging taking place predominately during off-peak hours, on-peak regional electrical demand would increase by 85 MW (3,400 MW off-peak) in 2015, which the report indicates would not result in the need for increased generating resources.

2. *How much additional electric generating capacity will be needed in the NESCAUM region if the EV mandate is adopted, assuming that significant EV battery charging occurs on-peak?*

   The report mentioned above also examines a scenario in which significant on-peak charging occurs, and finds that on- and off-peak electrical demand would increase by 871 and 3,482 MW, respectively. The report indicates that this would represent a 1-2% increase in regional electrical load. Given the current capacity glut in the Northeast, it appears likely that this additional demand could be met without additional generating resources.

3. *What are the projected net reductions in volatile organic compounds, oxides of nitrogen, sulfur dioxide, and carbon dioxide if the EV mandate is adopted (1) assuming that most EV battery charging occurs off-peak, and (2) assuming that significant EV battery charging occurs on-peak?*

   Relative to a LEV (low emission vehicle), the report mentioned above estimates that an EV charged predominately off-peak would achieve reductions of at least 0.18 g/mile VOC, 0.08 g/mile NO_x, and 172 g/mile CO_2. Because utility SO_2 emissions are capped, NESCAUM does not expect that EVs will result in a net increase in SO_2. The same report examines a scenario in which utility NOx emissions are higher, and finds that in that case NOx emissions associate with EV recharging are 0.02 g/mile greater than those of a LEV. However, it should be noted that the NOx budget supported by NESCAUM would ensure that EVs do not result in net increases in NOx from electrical generation facilities -- in this case, an EV would achieve reductions of 0.21 g/mile NOx. It should also be noted that

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[2] Tennis (for NESCAUM), *Impact of Battery-Powered Electric Vehicles on Air Quality in the Northeast States*, July 1992.

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upstream emissions associated with gasoline refining, storage, and distribution are not accounted for in this analysis. Preliminary results from a study under development by the Union of Concerned Scientists indicate that these emissions can be significant, and may greatly increase the net benefit of EVs.

4. *On page 3 of your testimony, you state that, in New York and Massachusetts alone, the already-adopted requirements related to ZEVs will result in the annual sale of over 100,000 ZEVs by 2003, and that if the mandate is required throughout the region, annual sales will exceed 400,000 by 2003.*

   More recent analysis performed by NESCAUM indicates that these estimates may be somewhat overstated: we currently estimate that the corresponding estimates would be approximately 85,000 (Massachusetts and New York) and 240,000 (regionwide).

   a. *What is the expected price differential for ZEV purchasers relative to conventional vehicles, and why do you believe that purchasers will be willingly to pay that price differential?*

      A recent study[3] prepared for the Northeast Alternative Vehicle Consortium (NAVC) predicts that economies of scale realized by 1998 will bring the purchase price of a conversion EV currently marketed for $22,500 down to $12,500. At that point, NESCAUM expects that any price differential relative to a conventional vehicle will be small enough that it will not constitute a major barrier to potential purchasers.

   b. *Given the current low volume of current production, who is going to supply all these vehicles?*

      The above-mentioned study notes that EV production processes may differ significantly from current conventional vehicle processes, and that volumes which would not be attractive to current major automakers may nonetheless be well-suited to smaller companies just entering the market. NESCAUM notes with enthusiasm that the study's prediction of agreements whereby major automakers sell "gliders" to small conversion companies appear as of recently to be an approaching reality.

5. *You also note on page 3 of your testimony that both New York and Connecticut have approved sales and/or income tax credits that would apply to the incremental costs associated with electric and other alternative fueled vehicles. What is the size of these credits, and by how much do they reduce the incremental costs?*

   The above-mentioned study reports that New York offers $1,076 per EV in sales tax credits, while Connecticut offers $2,413 in combined sales and income tax credits.

6. *One page 5 of your testimony you state that over the next three to five years, you expect to see significant performance improvements and cost reductions. What specific performance improvements and costs reductions do you expect?*

   NESCAUM anticipates at least moderate improvements in EV range and power in this time period. We also expect significant improvements in EV reliability and in cold-weather performance. With respect to cost, we note that the above-mentioned study predicts EV cost reductions of 35-45% within the next four years.

(continued)

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[3] Moomaw, et. al (for NAVC), *Near-Term Electric Vehicle Costs*, October 1994.

7. *What is the regional environmental impact of the eventual disposal of all the EV batteries if projected EV volumes are achieved?*

   NESCAUM anticipates that battery recycling capacity will be such that any such impacts will be avoided.

8. *On page 6 of your testimony you say that, in NESCAUM's view, State-level adoption of ZEV mandates provide the strongest incentive to rapidly develop appropriate EV technology. How exactly do you intend to force people to buy and drive EVs, which appear, for the foreseeable future, to be very expensive and limited in performance?*

   Because the ZEV mandate applies to the production and sale (as opposed to the purchase) of electric vehicles, buyers will under no circumstances be forced to purchase electric vehicles. NESCAUM observes that the ZEV mandate has provided potential manufacturers with a strong incentive to voluntarily invest funds in order to develop improved EV technologies and reduce costs. Numerous performance improvements have been reported in recent months and, as stated above, we expect to observe significant further improvements in the near future. Moreover, we expect that, as reported by the above-mentioned study, significant EV cost reductions will be realized over the next few years. NESCAUM therefore expects that people will choose to buy EVs as a matter of personal preference and voluntary choice.

ADDITIONAL STATEMENTS SUBMITTED FOR THE RECORD

CARTA

Chattanooga Area Regional Transportation Authority

June 28, 1994

VIA TELECOPIER

The Honorable Marilyn Lloyd
United States Congress
House of Representatives
2406 Rayburn House Office Building
Washington, Tennessee 20515-4203

Re: Advanced Research Projects Agency

Dear Marilyn:

I understand that your Subcommittee will receive testimony this Thursday from Major Richard Cope, who heads the electric vehicle development activities of the Advanced Research Projects Agency. In anticipation of his appearance, I wanted to brief you on Chattanooga's involvement with ARPA, and the very positive role that Major Cope and his agency have played in our efforts to push forward electric transit vehicle applications.

The Chattanooga Area Regional Transportation Authority and the Chattanooga-based, non-profit Electric Transit Vehicle Institute are members in two regional research consortia that are working with ARPA on electric vehicle technology development. Advanced Vehicle Systems, headed by Joe Ferguson, is also actively involved in these consortia and is working with a third consortium, as well.

Among the most significant ARPA projects in which we are presently involved are:

- Demonstration and testing in Chattanooga's Living Laboratory of integrated wheel motors, incorporating advanced, AC induction motors with integral gear reduction mechanisms. These motors will be tested in 22-foot and 31-foot buses that will be placed in service later this year in Chattanooga.
- Testing of advanced lead acid batteries in buses in Chattanooga' Living Laboratory.

Chattanooga's Driving Force.

1617 Wilcox Boulevard • Chattanooga, Tennessee 37406
Phone (615) 629-1411

- Demonstration and testing of high efficiency air conditioning and heating systems for electric vehicles featuring new heat pump compressor designs. The first of these systems will be incorporated in a bus that will be put into service in Chattanooga in the third or fourth calendar quarter of 1994.
- Demonstration and testing in Chattanooga's Living Laboratory of a rapid recharging system that will permit lead acid batteries that now take eight hours to recharge to be recharged in 20 minutes.
- Support for an Electric Vehicle Research Network unit that will be located in support of Chattanooga's Living Laboratory.

All of these advanced technology projects will be based in a large, electric vehicle workshop that CARTA has included in the Shuttle Park South Facility. Shuttle Park South is the first of the three intercept parking garages and Shuttle terminals funded through your leadership, and it should be substantially complete some time in July. The electric vehicle workshop area, about 10,000 square feet in size, is located adjacent to the Shuttle Plaza, through which electric buses will pull every five minutes. The workshop area will accommodate a small technical staff that will monitor and document the performance of advanced electric vehicle components that are being tested in the Living Laboratory under funding provided by ARPA and other sources.

We have also helped develop proposals for a series of exciting additional research and development activities that would benefit Chattanooga's development of electric vehicle activities. Among the proposals that have been submitted for consideration by ARPA in its 1994 funding cycle are:

- A development program to be undertaken principally by the University of Texas at Austin Center for Electromechanics that will produce an energy storage flywheel to be installed in a CARTA electric bus for demonstration and testing in Chattanooga's Living Laboratory.
- A related program to be undertaken principally by the University of Texas at Austin for development of a stationary energy storage flywheel that will permit the efficient utilization of rapid charging in Chattanooga, without adversely affecting utility load profiles.
- Development of a new type of electric motor that would be safer and less costly than current advanced motor designs. The research and development work would be undertaken by the University of Texas at Austin. Significant matching funds would be provided by a group centered in Chattanooga, which is interested in commercially producing the new motors.

- Development of an electromagnetic suspension that offers significant promise for applications in electric vehicles, particularly those using wheel motor components. This development work also is to be done by the University of Texas at Austin.
- Development of electric motor controller technology that would permit the rapid substitution of different energy storage devices, so that electric buses or other vehicles could be tailored to the daily missions that they are to undertake.
- Development and testing of additional designs of high efficiency air conditioner systems.

The financial support of the Federal Transit Administration earmarked for Chattanooga through your leadership permitted us to begin development and acquisition of electric transit vehicles. Chattanooga's involvement with electric vehicles could not have progressed so rapidly had it not been for the support of ARPA and the involvement of Major Cope.

ARPA has identified many of the most talented and innovative individuals and organizations that are promoting electric vehicle development. Major Cope has led, encouraged, and supported those that are doing pioneering technological work as well as those who are involved in the rapid application of technologies as they become available. ARPA's project selection and administration procedures have been innovative and practical.

I am sure that you will find Major Cope's presentation enlightening and informative.

Please let me know if I can provide you more information.

With best regards, I am

Sincerely yours,

Frederick L. Hitchcock
Chairman
CARTA Board of Directors

FLH/gb
cc: Ms. Nancy Jeffery
Mr. Thomas W. Dugan
Mr. L. Joe Ferguson

23052

AVS
Advanced Vehicle Systems, Inc.

June 29, 1994

Congresswoman Marilyn Lloyd
2406 Rayburn House Office Bldg.
Washington, D.C. 20515

Dear Marilyn,

I have received a copy of Rick Hitchcock's letter to you regarding a representative of ARPA appearing before your sub committee this Thursday.

Rick did an excellent job of explaining Chattanooga's activities with ARPA and I would like to make only a few additional comments.

You are aware that AVS came into being as a start up manufacturer of battery powered electric buses last year as a result of CARTA's receiving FTA funding, and AVS being the successful bidder, for twelve electric buses. We are up and running well presently and now employ about 30 people.

Just as CARTA has influenced our business, ARPA has played a major role in helping us push the state of the art forward through development projects with both major corporations and other small start up companies with "leap frogging" type technology.

Perhaps one of ARPA's greatest strengths is, to me, their "don't mess around, get the job done" attitude.

We respect the ARPA staff we have dealt with and are working hard for consideration in their RA 94 program.

Sincerely,

L. Joe Ferguson

LJF/vf

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EEI **EDISON ELECTRIC INSTITUTE**

THOMAS R. KUHN
President

July 15, 1994

The Honorable Marilyn Lloyd
Chairman
Committee on Science, Space and Technology
Subcommittee on Energy
U. S. House of Representatives
Washington, D. C. 20515

Dear Marilyn:

I am writing to request that the enclosed written testimony on behalf of the Edison Electric Institute (EEI) to the Committee on Science, Space and Technology, Subcommittee on Energy be included in the June 30, 1994 hearing record on Electric Vehicles and Advanced Battery Research.

EEI believes in the benefits and viability of electric vehicles and would like the opportunity to inform the Committee about a national initiative -- led by the electric utility industry -- to place electric vehicles into utility, commercial, government, and/or transit fleet applications beginning this year. This program is called EV America.

EV America will provide a mechanism for the introduction of greater numbers of electric vehicles into federal fleets, supporting the goals of the 1992 Energy Policy Act and the President's Executive Order on alternative fuel vehicles. EV America will be a key part of the utility industry's commitment to voluntary reductions of greenhouse gas emissions through the Climate Challenge program. It supports the goals of the Clean Cities program and the Clean Air Act, and compliments the objectives of the Partnership for the Next Generation of Vehicles.

The electric power industry stands ready to be a partner, but federal government commitment and adequate funding for the program is needed. We urge the Committee's support in ensuring that the federal government will be a partner in EV America.

Sincerely,

Thomas R. Kuhn

TRK:jmc

Enclosures

cc: The Honorable George Brown
The Honorable Harris Fawell

Written Testimony of the Edison Electric Institute
Submitted to the Committee on Science, Space and Technology
Subcommittee on Energy
U.S. House of Representatives
Hearing on Electric Vehicles and Advanced Battery Research
June 30, 1994

Introduction

This statement is being submitted on behalf of the Edison Electric Institute (EEI). EEI is the association of investor-owned electric utilities. Our member companies serve 99 percent of all customers served by the investor-owned segment of the industry. They generate approximately 78 percent of all the electricity in the country and serve 76 percent of all ultimate customers in the nation.

EEI appreciates the opportunity to submit a statement concerning the electric vehicles and advanced battery research. Electric vehicles, in federal, state and private fleets will yield significant environmental benefits. Diversifying the forms of energy utilized for transportation enhances domestic energy security, provides new business opportunities within the U.S. economy and creates high value domestic jobs.

There is currently a myriad of laws, regulations and incentives concerning alternative fuel vehicle programs. These programs include the alternative fuel vehicle programs in the 1992 Energy Policy Act (EPAct), the Clean Air Act, President Clinton's Executive Order and recommendations from the Federal Fleet Conversion Task Force, the Clean Cities Program and the Climate Change Action Program. Electric vehicles have an important role to play in each of these programs, and efforts by both the public and private sectors to assure that the benefits of EVs are realized in these programs must be a high priority.

The electric utility industry is doing something to help ensure that EVs are included in these various alternative fuel vehicle programs. EEI and three other national organizations -- the Electric Power Research Institute, the Electric Transportation Coalition and the Electric Vehicle Association of the Americas -- have organized a program designed to advance the introduction of electric vehicles. We intend, through large purchases of vehicles in targeted demonstration projects, to provide fleet managers and consumers with information, experience and confidence in the ability of EVs to meet their needs. This program is called EV America.

EV America - A General Description

The central element of EV America is a joint, voluntary effort -- led by the electric utility industry -- to coordinate the purchase of a significant number of qualifying EVs to be demonstrated in utility and government fleets. EV America is a partnership between the private sector and government to undertake a large-scale demonstration, test and evaluation of electric vehicles and the deployment of associated vehicle support systems. As such, it is a key element of the Climate Challenge program.

The objective of the first phase of the EV America market demonstration is to place 500 EVs into utility, government or other "control" fleets by the end of calendar year 1995. Thirteen utility industry CEOs have signed the EV America "memorandum of understanding" committing utilities around the nation to participation in EV America. Phase II has a goal of placing up to 5000 EVs in private and government fleets by the end of calendar year 1997.

The 13 utilities already committed to EV America serve over 20 million customers in eight states and the District of Columbia. Twenty six additional electric utilities, representing an additional 25 million customers, have expressed a desire to participate in EV America. As shown on the enclosed maps listing the EV America participants and allies, this geographic diversity ensures that EVs will be introduced in many important markets across the United States.

EV America participants will aggregate purchase orders and/or purchase, directly or indirectly through other fleet owners or operators, a large number of EVs for use in utility and government fleets. Utilities will provide recharging, technical and maintenance support for electric vehicles. The program will help provide fuel supplier information, evaluate performance of the vehicles, identify opportunities and challenges associated with energy services for electric vehicles, and provide support for vehicle owners.

EV America Can Contribute To Implementation of the Energy Policy Act and Federal Economic and Environmental Objectives

EV America can further federal objectives in that it will:

- Provide a mechanism for the introduction of greater numbers of EVs into federal fleets, supporting the goals of EPAct, and the President's Executive Order on alternative fuel vehicles;
- Facilitate the use of electric vehicles by electric utilities subject to the fuel providers program of EPAct;

- Be a key part of the utility industry's commitment to voluntary reductions of greenhouse gas emissions through the Climate Challenge program, in partnership with the DOE;
- Support the federal government's efforts to introduce alternatively fueled vehicles to other public and private fleets through EPAct requirements and the Clean Cities program;
- Address the objectives of the EV and EV infrastructure demonstration programs authorized in EPAct;
- Develop, utilize and condition the market for technologies that will support the "Partnership for the Next Generation Vehicle"; and
- Help to ensure a domestic EV industry that can enhance international competitiveness, create new jobs and preserve the environment.

EV America Supports DOE's Goals

Federal support for EV America will help ensure balance in the implementation of the administration's alternatively funded fleet vehicles by including electric vehicles. The acquisition of EVs through EV America is consistent with and supports DOE's goals. The Department of Energy has been authorized through the Energy Policy Act of 1992 to coordinate and provide leadership in the transition to alternative fuels in the transportation sector. Additionally, EPAct authorizes DOE to undertake a large-scale commercial demonstration program of EVs and a program to support systems to operate these vehicles. Cooperation with EV America offers DOE an important means to fulfill these responsibilities.

In a June 10, 1994 DOE draft report entitled "Encouraging The Purchase and Use of Electric Motor Vehicles," the Department recommends that "The Federal government should increase its commitment of funds to purchase EVs for the Federal fleet. Continued EV-related programs and increased Federal purchase of EVs will demonstrate the government's commitment to EVs and strengthen consumer confidence in the EV market."

EV America will provide a mechanism to include electric vehicles in federal fleet conversion initiatives and help the Department of Energy (DOE) to meet its stated objectives to have 1,500 EVs in federal fleets in fiscal year 1995 and 5,000 EVs in federal fleets by 1996.
EV America is well-suited to help meet DOE's goals and objectives. We believe EV America will help DOE and other various federal agencies, including the Department of Defense and the General Services Administration, to coordinate integrated alternative fuel programs that will include EVs.

Funding for EV America

The electric utility industry has taken the lead. Private industry has committed to provide 55 percent ($12 million) of the $22 million in total cost needed to implement Phase I (500 EVs by 1995). But the utilities involved in EV America need the participation of the federal government to assure that our goals for electric vehicles are realized.

For Phase I, EV America is seeking $10 million from the Federal government. Funding sources have been identified both within the Department of Energy and the Advanced Research Projects Agency of the Department of Defense. In particular, the Department of Energy should be an active participant in the EV America program.

To support EV America, the maximum possible funding for the Department of Energy's Site Operators User Task Force program should be provided in FY 1995. This program has a long history of utility-government cooperation on EVs which can support the attainment of the EV America Phase I program goals. Additionally, a portion of the funds appropriated to DOE for the acquisition of alternatively fueled vehicles should be made available for acquisition of EVs in cooperation with EV America. Finally, as part of the evolving relationship between the Departments of Defense and Energy on EV-related issues, a portion of funds available to ARPA for its EV and EV infrastructure program should be devoted to support EV America.

Summary

EV America is an important component of the President's Climate Change Action Plan. It is a major initiative under the utility climate challenge, a voluntary partnership between the electric utility industry and the DOE to address the issue of greenhouse gas emissions. EV America will also support the Clean Cities program and state efforts to meet the requirements of the Clean Air Act. It compliments the objectives of the Partnership for the Next Generation of Vehicles. The EV America program will assist DOE and the Defense Department in implementing the EV and EV infrastructure programs authorized by Congress. It will ensure that EVs are included in federal fleets as the Administration proceeds with increased acquisitions of alternative fuel vehicles.

The geographic diversity of EV America participants ensures that EVs will be introduced in many important markets across the United States. A self-sustaining, vigorously competitive nationwide market for EVs will be stimulated through the careful introduction of electric vehicles into controlled fleet applications. Placement of a significant number of EVs on America's roadways will also serve to demonstrate the environmental benefits of EVs. We urge the Committee's support in ensuring that the federal government will be a committed partner in EV America.

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.

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July 19, 1994

Ms. Marilyn Lloyd
Chairwoman
Subcommittee on Energy
Committee on Science, Space and Technology
United States House of Representatives
Washington, D. C. 20515

Dear Madam Chairwoman:

On behalf of the Advanced Lead Acid Battery Consortium (ALABC), I greatly appreciate the opportunity to present written testimony in support of the Subcommittee's June 30, 1994, hearing on the Department of Energy's Advanced Battery programs.

ALABC salutes the Subcommittee for exercising its oversight responsibilities of DOE's advanced battery programs. ALABC looks forward to working with the Subcommittee over the coming months in support of U.S. efforts to promote the technical and commercial viability of EVs.

Many thanks for your continued support for EV initiatives. Please let me know if you or your staff need additional information with regard to ALABC.

Sincerely,

For

Jerome F. Cole
President

Attachment

cc: Rick Piltz

WRITTEN STATEMENT OF
DR. JEROME F. COLE
PRESIDENT, ADVANCED LEAD ACID BATTERY CONSORTIUM
BEFORE THE
SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

July 14, 1994

On behalf of the Advanced Lead Acid Battery Consortium (ALABC), I greatly appreciate the opportunity to present written testimony to the Subcommittee on Energy. The ALABC recognizes the important role the Subcommittee plays in the oversight of the Department of Energy (DOE), and is pleased to provide the Subcommittee with an industry perspective on DOE's sponsorship of advanced battery research and development programs.

In addition to describing ALABC efforts to optimize lead-acid batteries in support of electric vehicle applications, ALABC will also provide its views regarding the Department of Energy's efforts to support the development of advanced battery technology for electric vehicle applications.

The Advanced Lead Acid Battery Consortium (ALABC) is a United States-based international consortium of lead-acid battery companies and supporting industries. ALABC strongly believes lead-acid technology is the most cost-effective, near and medium-term power source for electric vehicles (EVs). ALABC views its research initiatives as the foundation for commercial and U.S. Government efforts to develop "breakthrough" advanced battery technologies.

In recent years, a series of legislative initiatives have essentially mandated the reemergence of battery-powered electric vehicles (EVs).

The 1998 California mandates require 2% of new car sales to be zero-emission vehicles (ZEVs). The 1998 mandates have created a major economic opportunity for the battery industry and the makers of EVs. The most urgent need for the coming fleet of EVs is a suitable battery. In response to this need, the Department of Energy, the Electric Power Research Institute, and the automotive Big Three (Ford, General Motors and Chrysler) established the United States Advanced Battery Consortium (USABC). The USABC has categorized potential battery technology as either mature (near-term), developmental (mid-term) or experimental (long-term) and is focusing its efforts on mid and long-term technologies.

Based primarily on USABC's exclusion of lead-acid technology, the ALABC was formed in 1992 by domestic and international companies with membership now representing 90% of U.S.-based battery production capacity.

USABC defines a mid-term technology as one with the potential of being mass produced as an EV battery in this decade. However, data on existing and proposed EVs strongly indicate that the emerging fleet of EVs will be predominantly powered with lead-acid batteries through the remainder of this decade and well into the next. The lead-acid technology, especially Valve Regulated Lead Acid (VRLA) technology, has many inherent advantages including: abundant, low-cost, non-polluting materials; safe, ambient temperature operation; and an existing infrastructure for manufacturing, servicing and recycling.

The prevalence of lead-acid technology, for example, is reflected in EV programs funded by the Advanced Research Projects Agency (ARPA) Of the 318 vehicles contains in ARPA's Electric/Hybrid Vehicle Program, 247 are presently using lead-acid technology. In addition 63 of the 318 vehicles are leaning toward the use of lead-acid technology. At the Department of Energy, vehicles included in DOE's Site Operators Users Task Force are driven almost exclusively by lead-acid batteries.

ALABC is currently carrying out a research plan designed to produce within four years an advanced lead-acid battery system suitable for powering EVs. ALABC's research and development program targets three areas needing improvement, including:

- specific energy (Wh/kg) and battery life
- battery system monitoring and control
- rapid recharge optimization

Specific goals of ALABC's Research Plan include the achievement of the following objectives in a manufacturable VRLA:

- A minimum specific energy of 50Wh/kg at the C/3 rate
- A minimum specific power of 150 W/kg at 80% depth of discharge
- A cycle life of 500 Simplified Federal Urban Driving Schedule (SFUDS) cycles over 3-years with less than 20% performance degradation
- Compatibility with rapid recharging, with the following performance objectives:
    - 50% recharge in 5 minutes or less
    - 80% recharge in 15 minutes or less
    - 100% recharge in 4 hours or less
- An original cost of less than $150/kWh exclusive of recycling credits

ALABC is funding research in support of these objectives through member contributions and matching funds from U.S. Government organizations. Initially estimated as a $19 million four year program, ALABC has to date committed $7.8 million in commercial and government funding toward advanced lead-acid technology development.

ALABC members have a vested interest in developing an advanced lead-acid battery that is optimized for EVs and can win a share of the EV battery market. Cooperation between usual competitors is occuring because of the anticipated large market, the urgency of being prepared to meet the 1998 mandate. Toward this end, ALABC believes the Department of Energy should be doing more to support the development of advanced lead-acid batteries.

When contrasted with the hundreds of millions of dollars being spent by the U. S. Government in support of advanced battery research, the funding required to optimize the lead-acid battery for EV applications is extremely modest. For example, the performance goals contained within ALABC's research plan could be achieved for a total industry and government investment of under $10 million. Such an investment would have an immediate economic return based on the reality that an optimized VRLA batter would be EV battery of choice needed to meet the 1998 mandate.

ALABC's mission is entirely complementary with the advanced battery initiatives being sponsored by the Department of Energy. As such, ALABC would welcome the opportunity to work more closely with the Department of Energy in support of the U.S. Government and industry efforts to meet the 1998 mandates.

ALABC salutes the Subcommittee for exercising its oversight responsibilities of DOE's advanced battery programs. ALABC looks forward to working with the Subcommittee over the coming months in support of U.S. efforts to promote the technical and commercial viability of EVs.

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